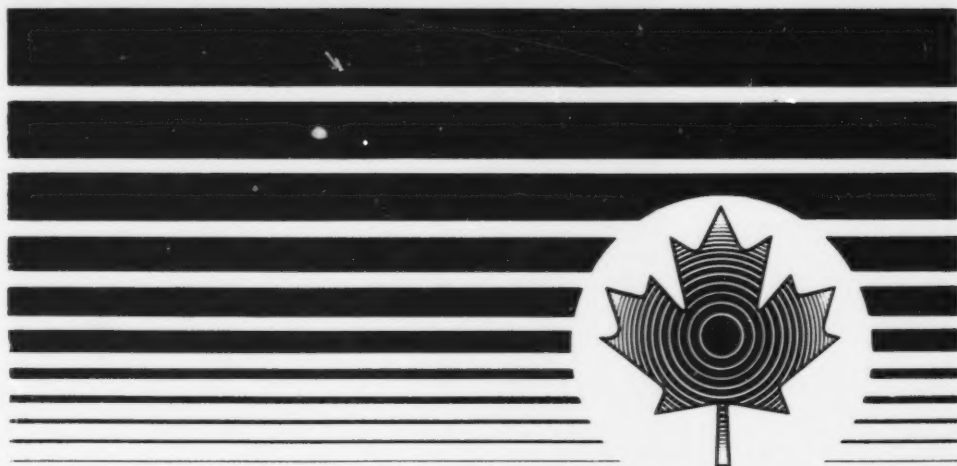


Impacts of Canada's Uranium Mining Industry

**Marvin Shaffer and Associates Ltd.
G.J. Holman, Principal Investigator**



CANADIAN ENERGY RESEARCH INSTITUTE

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Preface

This report was prepared for the Canadian Energy Research Institute. I would like to thank the Institute, and, in particular, the Uranium and Nuclear Energy Branch of Energy Mines and Resources Canada for its assistance and support. It should be noted that the views and conclusions expressed in this report are strictly those of Marvin Shaffer and Associates Ltd.

G. J. Holman, Economist
Marvin Shaffer and Associates Ltd.

Chapter 1

GENERAL REVIEW OF THE URANIUM INDUSTRY IN CANADA

1.1 Introduction

The purpose of this study is to examine economic and environmental impacts of uranium mining in Canada and to compare these impacts with those of other selected extractive and energy industries.

Like all extractive industries, uranium mining generates considerable direct and indirect employment and income impacts, not only in the region of activity, but throughout the country. A principal objective of this study is to estimate the magnitude and distribution of the impacts that uranium mining may contribute to the economy over the next 20 years.

While uranium mining is in many ways similar to other extractive industries, in certain important respects it is different. Economically it differs in terms of the value and direct income generated by its production. Uranium is a very high value metal, much higher than many others, and consequently yields very high incomes and government revenues per kilogram of production.

Environmentally and socially uranium mining is perceived differently from other industries because of the important health and safety concerns that its production and downstream use raise. Environmental and social issues surrounding uranium mining are reviewed in this study. They too are compared or put in the perspective of the health and safety concerns raised for other extractive and energy industries.

An overall assessment of uranium mining is undertaken at the end of the study. An attempt is made to place the impacts and costs in perspective and to provide a more objective understanding of the issues associated with uranium mining in Canada. Possible measures which can be implemented

to maximize the net benefits of uranium mining are also outlined.

1.2 Resource Description

Uranium is one of the most widespread of all metals. Traces of uranium can be found at background levels and higher, in ocean water, ground and stream water, and in rocks. Uranium also occurs naturally with such minerals as coal, gold, silver, molybdenum, copper and phosphate rock and is now commercially recovered as a by-product of several of these minerals.¹

All of the uranium commercially mined in Canada is used in nuclear reactors throughout the world for the generation of electricity. Medical and other industrial applications of radioactive materials involve uranium indirectly as an irradiating source (for production of radioactive isotopes) or in the form of waste from the uranium enrichment process. These latter applications therefore do not constitute primary demand for Canadian uranium.

The following is a brief description of the various stages of uranium discovery, development and utilization.

1.2.1 Exploration

This stage can involve three levels of activity.²

- Regional Exploration: This includes compilation and assessment of existing information and the collecting of further data by means of airborne and ground geophysical surveys; geological mapping; sediment, soil and water sampling and analysis. This level of exploration attempts to delineate areas of uranium resource potential.
- Detailed Ground Exploration: Procedures such as geophysical and geochemical surveys (often requiring line cutting), road building, trenching and stripping and drilling are designed to evaluate thoroughly local areas of interest.
- Detailed Subsurface Exploration: Systematic drilling and sampling and/or digging of small surface pits or underground shafts and adits provide more detailed information upon which to evaluate recovery feasibility.

1.2.2 Mining

Uranium mining methods are typical of other types of hard rock mining and are of the same two primary types-- underground and open pit. Underground mines occur where the depth, physical dimensions or other characteristics are unsuited for surface mining as in the Elliot Lake Region.

Open pit mining occurs where deposits are near the surface and have a substantial horizontal dimension, as in northern Saskatchewan. Saskatchewan deposits are generally very much richer in uranium content than existing Ontario deposits.

Typical underground mining operations include such facilities as service buildings, a head frame with a loading facility, conveyors, a mine waste pile and a flow of water from underground sumps pumped to the surface for use in the mill and concentrator. The area occupied above ground may be only a few acres. However, underground openings may extend for many miles.

Open pit mining tends to be more capital intensive, involving blasting and loading onto large diesel trucks which transport the ore to the mill. Open pit uranium mining can typically extend for 3000 acres and is characterized by a variety of stockpiles including overburden, waste rock, marginal ore and refinable ores. Disposal of large tonnages of overburden and waste rock is an important part of both underground and surface mining.

A very recent mining method is called in-situ leaching whereby uranium is recovered by placing dissolving chemicals into drill holes or upon ore piles above ground. These chemicals are recovered and processed to remove the uranium. This method is acceptable where uranium occurs in porous mineralizations such as sandstones, but its future use is expected to be limited because of unfavourable geological conditions in most natural occurrences of uranium in Canada.

1.2.3 Milling

Uranium milling operations are similar to chemical extractive processes for metal ores and contain crushing machinery, receiving bins, screening equipment, conveyors and a chemical treatment facility. The ore is crushed, ground

and leached by chemical percolating to dissolve uranium minerals. After solid/liquid separation and further purification, uranium is usually chemically recovered from a solution as a precipitate. This concentrate is heated, pulverized and drummed for shipment as a powdery material called 'yellowcake'. The wastes, known as tailings, are contained in a slurry of finely ground solids which are transferred to a tailings pond for settling.

1.3 Magnitude and Location of Canadian Resources

An annual assessment of Canada's uranium resources is conducted by the Uranium Resource Appraisal Group (URAG) within Energy, Mines and Resources Canada. Their 1979 assessment of resources associated with already identified deposits, categorized by degree of certainty³ and cost, is outlined in Table 1.1.

TABLE 1.1

1979 ESTIMATES OF CANADA'S MINEABLE URANIUM
'000 TONNES U CONTAINED IN MINEABLE ORE^a

Price Assumption	Measured	Indicated	Inferred	Prognosticated
Up to \$130/kg	73	157	238	143
\$130 to \$200/kg	<u>4</u>	<u>25</u>	<u>90</u>	<u>299</u>
	77	182	328	442

^aMineable ore is generally 75%-85% of ore-in-place for underground operations and higher for open pit operations. Note that these estimates do not include processing losses which averaged about 7% for existing conventional operations in 1979.

SOURCE: Uranium Resource Appraisal Group, Energy, Mines and Resources Canada.

It should be noted that almost 90 percent of the measured, indicated and inferred resources is associated with deposits that are either being mined or are committed for

production.⁴ However, there are substantial undiscovered or prognosticated resources associated with known deposits. Also, because all resource categories shown in Table 1.1 are associated primarily with already identified deposits, they represent an incomplete appraisal, particularly for lower grade material mineable only within the higher price range.

URAG, as part of the recent International Fuel Cycle evaluation (INFCE) which culminated in 1980, estimated that, on the basis of resources associated with known deposits, production in Canada could be maintained at levels exceeding 10,000 tonnes of uranium per year until 2025.⁵

A joint evaluation of world uranium and thorium resources by the Nuclear Energy Agency and the International Atomic Energy Agency⁶ estimated that Canada accounted for about 12 percent of the world's total reasonably assured resources⁷ of uranium.

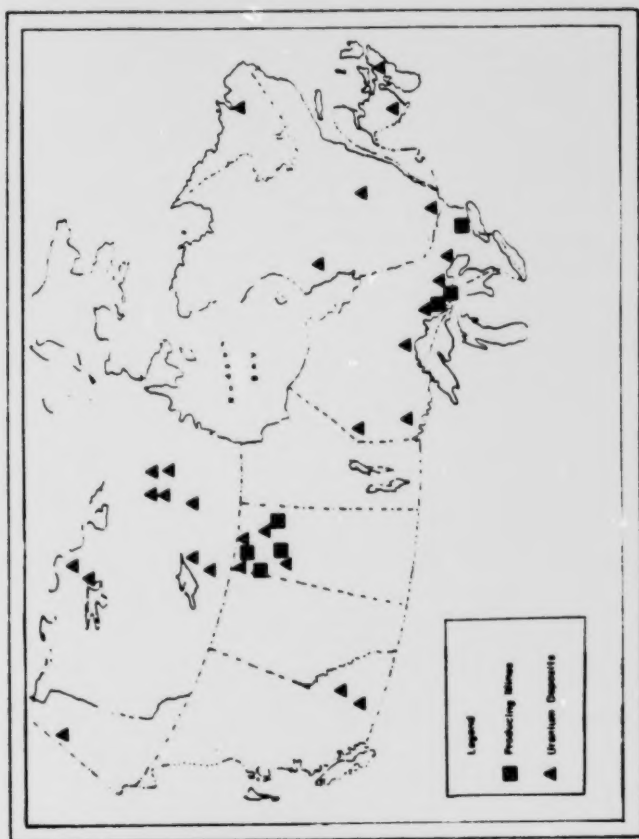
With respect to 'estimated additional resources'⁸ Canada now accounts for 30 percent of the world's total, ranking second only behind the U.S.

Of total discovered uranium resources in Canada, about 62 percent is in Ontario and 33 percent in Saskatchewan. Together, Ontario and Saskatchewan account for about 95 percent of Canada's uranium resources, with the latter growing in importance as a potential supplier.

The map following indicates areas in Canada with uranium production and resources. (See page 6.)

1.4 The Development of the Uranium Industry in Canada

The first production of uranium in Canada began in 1942¹⁰ at the Eldorado Gold Mining Company's deposit at Great Bear Lake, Northwest Territories, as a result of nuclear weapons development in the United States. In the following year Eldorado was acquired by the federal government and became a Crown corporation. After this it acted as an agent of the federal government, negotiating contracts for intergovernmental purchase and resale of uranium concentrate for other private producers. This role continued until 1958.



AREAS IN CANADA WITH URANIUM PRODUCTION AND RESOURCES

In recognition of uranium's strategic importance, the Atomic Energy Control Act was passed in 1946 which gave the federal government regulatory authority over this resource. The Atomic Energy Control Board (AECB) was established to administer the provisions of this Act. Since its beginnings federal regulatory policy and the strength of export markets have played a key role in the development of the industry.

Active prospecting by private industry began in 1948 under the close control of the AECB. In 1952, a low-grade uranium-bearing conglomerate was discovered in the Elliot Lake region of Ontario. By 1957, Denison and Rio Algom had established their mining operations and this area had become Canada's leading producer of uranium.

The commercial era of the uranium industry began in 1958 when private producers were first allowed to do their own marketing. It was also that year that the policy of uranium exports for peaceful purposes only was enunciated. Production of uranium reached an all-time peak of 12,225 tonnes in 1959 and its export value exceeded that of any other metal or mineral for that year. Since 1959, Canada has ranked second in the world behind the U.S. in terms of uranium production volumes.

Ironically, it was also in 1959 that the U.S. Atomic Energy Commission (USAEC) announced it would not extend its options to purchase additional uranium from Canada. In response to a collapse in demand resulting largely from the shift away from military markets, the federal government initiated the first of several stockpiling programs which were to extend from 1963 to 1974.

Over this period the federal government established, through amendments to the Atomic Energy Act and directives from the Minister of Energy, Mines and Resources, the policy framework for uranium development and marketing which exists today. In 1965, and again in 1969, the policy of allowing uranium exports for peaceful purposes only was reiterated. In 1966-67 the first major long-term commercial sales were made and exploration resumed after a 10-year hiatus. In 1969, it was established that all contracts for the export of uranium would be examined by the appropriate federal agency

with respect to nuclear safeguards, the relationship between contracting parties, reserves, rate of exploration, degree of domestic processing, and selling and pricing policy. Further, it was stated that approval of contracts of greater than 10 years duration would be dependent upon provisions for renegotiation of price and subject to annually renewable and conditional permits.

Uranium markets remained depressed in the early 1970's because of production over-capacity, the existence of large inventories and stockpiles, the market power of large consuming utilities and policies of the USAEC and U.S. government policies designed to protect domestic utilities and producers.¹¹

In response to this situation, the federal government in 1972 authorized officials of two Crown corporations, Eldorado Nuclear and Uranium Canada Ltd., to undertake informal marketing arrangements with international uranium producers regarding the non-U.S. market.¹² The Canadian government supported this informal arrangement with directives under the AEC Act which essentially established minimum selling prices and the equitable allocation of sales volume (supply being greater than demand) among uranium producers.

The Arab oil embargo of 1973 gave a sharp boost to uranium demand. Nations heavily dependent on foreign oil began to markedly expand nuclear power programs and utilities began to seek longer-term purchasing arrangements for uranium. Around the same time curtailment of uranium supply occurred for various reasons in Australia, France and South Africa. By 1974, total future Canadian sales of some 38,000 tonnes had been negotiated, about 10 times the annual production level. In the face of these heavy demands, the Minister of Energy directed the AECB to ensure that uranium producers maintain reserves for the domestic nuclear power industry and that utilities maintain contracted forward supplies of uranium to ensure long-term nuclear reactor operation.

In 1974, India detonated a nuclear device utilizing plutonium produced by a Canadian-supplied research reactor. As a result, customers for Canadian uranium were asked to provide binding assurance that Canadian nuclear material or equipment would not be used to produce explosive devices.

By the end of 1974, uranium prices had approximately doubled over the previous year and were well over the Canadian government's minimum directed price. In 1975 the federal government informed the industry that all new contracts were to be based on an escalating floor price or world price, whichever was higher. In 1976, Canada required its customers to ratify the non-proliferation treaty or accept international safeguards on their entire nuclear program.

By 1977, a number of factors such as the slowing of growth in electricity demand, public apprehension regarding health, safety and environmental consequences of nuclear power, and high interest rates, had led to cutbacks in domestic and international reactor programs. In a situation of short-term oversupply, long-term contract prices levelled off or declined and 'spot' market prices dropped significantly.

Table 1.2 reflects the cyclical nature of the Canadian uranium industry, showing marked fluctuations in shipments over time, and the considerable decline from a peak level of 12,225 tonnes in 1959. Provincial shares of Canadian shipments have also varied considerably, but Saskatchewan's share is on a generally rising trend.

Uranium exploration expenditures, even when adjusted for inflation, increased steadily from 1975 to 1979 in response to rising prices over this period. In nominal terms, expenditures increased from \$23.9 million in 1975 to an estimated \$128 million in 1980. (See Table 1.3)

1.5 Current Profile of the Canadian Uranium Industry

1.5.1 Current and Planned Operations

There are currently 7 companies operating 8 mines in Canada. Three of these mines are in Saskatchewan, 2 of which are open pit operations. Ontario has 5 mines, 4 of which are underground and 1 of which uses an underground and surface heap-leaching technique.

There are a number of planned and committed operations scheduled to come onstream. Rio Algom is currently proceeding with the rehabilitation of the Stanleigh mill and

TABLE 1.2
URANIUM SHIPMENTS BY PROVINCE
(selected years)

Year	Saskatchewan		Ontario		Canada
	Tonnes	Percent Share	Tonnes	Percent Share	Tonnes
1980	2093	32.9	4275	67.1	6368
1979	2525	38.7	4005	61.3	6530
1978	3756	45.7	4455	54.3	8211
1975	609	13.1	4041	86.9	4650
1970	586	18.7	2553	81.3	3138
1965	788	23.2	2609	76.8	3397

SOURCE: Statistics Canada 26-202.

TABLE 1.3
URANIUM EXPLORATION EXPENDITURES IN CANADA
(\$'000,000)

1980	128.3 ^a
1979	129.5
1978	90.0
1977	71.7
1976	43.5
1975	23.9

^aPreliminary estimate.

SOURCE: Uranium Resource Appraisal Group, Energy, Mines and Resources Canada.

underground mine at Elliot Lake. Denison is also rehabilitating its Stanrock underground mine at Elliot Lake. Amec has completed construction of Phase I of the Cluff Lake mine and mill and its first full year of production will be in 1981.

The Key Lake open pit mine and mill in Saskatchewan has received approval in principle and is expected to be in production by 1984. Proposed open pit operations in Saskatchewan at Midwest Lake and Collins Bay are now in the planning stages and will be subject to regulatory approval. Table 1.4 summarizes the operations of existing and planned uranium mines and mills in Canada.

Table 1.5 outlines the ownership structure of the major uranium producers in Canada. Four out of the 7 current uranium mine operations in Canada are foreign-owned, accounting for about 66 percent of uranium production in Canada.

1.5.2 Production and Employment

Canada's 1980 uranium shipments totalled 6368 tonnes¹³ valued at \$638 million, about two-thirds of which originated in Ontario. An estimated 5400 tonnes of uranium valued at \$565 million were exported in 1980, representing about 85 percent of the volume and value of Canada's total uranium shipments.

Uranium mining and milling operations in Canada directly employ approximately 5700 people, 47 percent of which were in mining, 12 percent in milling, with the balance in administrative and general areas. Ontario accounts for over 80 percent of total mining and milling employment. This reflects the higher level of production and the labour intensive nature of underground mining which predominates in Ontario.

1.5.3 Exploration

Relatively high uranium price levels over the past several years have resulted in very active exploration programs in Canada. However, the results of recent URAG surveys presented in Table 1.6 show that exploration expenditures have levelled off in nominal terms and declined in real terms as a result of the recent levelling and decline of market

TABLE 1.4
CANADIAN URANIUM ORE PROCESSING PLANTS

Plant	Location	Nominal Daily Capacity (tonnes U of ore)	Annual Production Rate (a) (tonnes U)	Type of Mine
A. Operating				
Agnew Lakes Mines Ltd. Agnew Lake, Ont.	Agnew Lake, Ont.	n.a. (b)	172	In-Situ
Denison Mill -- Denison Mill	Elliot Lake, Ont.	6,440 (c)	1,749	Underground
Eldorado Nuclear Ltd.	Eldorado, Sask.	1,400 (d)	2,045	Underground
Gulf Minerals Canada Ltd.	Rabbit Lake, Sask.	1,590 (f)	233	Open Pit
Madawaska Mines Ltd.	Bancroft, Ont.	1,360		Underground
Rio Algom Ltd.	Elliot Lake, Ont.	6,150	2,036	Underground
-- Panel Mill	Elliot Lake, Ont.	2,990	152	Underground
-- Panel Mill	Cluff Lake, Sask.	1,360 (g)	1,500	Open Pit
Asak Limited				
B. Committed				
Rio Algom Ltd.	Elliot Lake, Ont.	4,540 (h)	-	Underground
ESL Resources Ltd.	Calgary, Alta.	-	40	Mill
May Lake Mining Corp.	May Lake, Sask.	-	-	
C. Planned and Possible (?)				
Brinco Ltd.	Muklovik, Nfld. (k)	-	-	
Consolidated Reaserp Minerals and Chemicals Ltd.	Birch Is., B.C. (l)	-	-	
Sasol Minerals Canada	Midwest Lake, Sask. (m)	-	-	
Norcen Energy Resources Ltd.	Beaverdell, B.C. (n)	-	-	
Rio Algom Ltd. - Milliken Mill	Elliot Lake, Ont.	-	-	
Gulf Minerals Canada, Ltd.	Collins Bay, Sask.	-	-	

- (a) 1980 production for operating plants; planned rate for others.
 (b) Using an underground and surface heap-leaching technique; to be phased out despite temporary renewal of production.
 (c) Planned expansion delayed due to fire.
 (d) Operated at about half nominal capacity in 1979. (The decision to close down the operation was made as this study was being completed.)
 (e) Joint venture with Uranerz Canada Ltd.; operating in excess of nominal capacity, 1,800 tonnes U to be achieved by 1984.
 (f) Daily capacity of 1,360 tonnes and annual production of 2,045 tonnes U to be achieved by 1984.
 (g) Rehabilitation to be completed 1984.
 (h) Recovered as by-product of phosphoric acid production.
 (i) Feasibility study completed; construction completed, but no firm decision as to timing and size of operations.
 (j) Feasibility study completed; construction completed, but no firm decision as to timing and size of operations.
 (k) Development suspended due to 7-year provincial moratorium.
 (l) Development pending regulatory approval.

SOURCE: Uranium in Canada, Energy, Mines and Resources Canada, op. cit.

TABLE 1.5
OWNERSHIP STRUCTURE IN THE URANIUM INDUSTRY

Producer	Ultimate Owner ^a	Percent Ownership	Source of Control
<u>A. Operating</u>			
1. Agnew Lake Mines (Agnew L., Ont.)	Kerr Addison Mines	100.0	Canada
2. Denison Mines (Elliot L., Ont.)	Denison Mines	100.0	Canada
3. Eldorado Nuclear Eldorado, Sask.	Government of Canada	100.0	Canada
4. Gulf Minerals Canada (Rabbit L., Sask.)	Gulf Oil Corp.	100.0	U.S.
5. Uranerz Canada ^b (Rabbit L., Sask.)	C. Deilmann AG	50.0	W. Germany
	Rheinische-Westfalische AG	50.0	W. Germany
6. Madawaska Mines (Bancroft, Ont.)	Federal Resources Corp.	51.0	U.S.
7. Rio Algom (Elliot Lake, Ont.)	Rio-Tinto Zinc Corp.	51.4	U.K.
8. Amok Ltd. ^c (Cluff L., Sask.)	Campagne Francaise des Minerais d'Uranium ^d	37.0	France
	Pechiney Ugine Kuhlmann	25.0	France
	Commissariat a l'Energie Atomique (state owned)	38.0	France
9. E.S.I. Resources Ltd.	Earth Sciences, Inc.	100.0	U.S.

^aIn some cases (e.g. Rio Algom) ultimate ownership is indirect and must be traced through subsidiaries.

^bUranerz Canada is joint owner (49%) of Gulf Minerals' Rabbit Lake operation.

^cSaskatchewan Mineral Development Corporation has recently acquired 20% of Amok.

^dPart of the Rothschild Group, Europe.

SOURCES: Inter-Corporate Ownership, Statistics Canada 61-517, and Uranium in Canada, Energy Mines and Resources Canada, Report EP-80-3, September 1980.

prices. Uranium exploration in 1980 involved some 377 projects and 113 companies or joint ventures.

Exploration is currently highest in Saskatchewan and the Northwest Territories. In 1980 these two areas accounted for 60.3 and 22.7 percent, respectively, of total expenditures. Exploration activity has virtually ceased in B.C. as a result of the moratorium on uranium activity. Table 1.6 outlines uranium exploration expenditures in Canada by province for the years 1978-1980. Approximately one-half the operators responding to the survey were companies whose majority interests were held outside of Canada.

1.5.4 Status of Industry by Province

In British Columbia, a 7-year moratorium on uranium exploration and mining was declared on February 27, 1980 because of concerns over the environmental impacts of these activities. In September, a regulation was passed designed to stop all types of mining and exploration involving significant concentrations of uranium.¹⁴ As a result, field exploration has virtually ceased and Norcen's proposed Blizzard project about 50 kilometres southeast of Kelowna has been indefinitely delayed. The B.C. Royal Commission of Inquiry into Health and Environmental Protection in Uranium Mining established by the province one year prior to the moratorium declaration was discontinued. The Commission forwarded its final report to the government on October 30, 1980. Although not able to complete its hearings, the Bates Commission recommended that exploration be allowed subject to conditional licensing but that mining be permitted only after deficiencies in existing regulations and in the setting of health and environmental standards are remedied.¹⁵

In Saskatchewan, the Cluff Lake Board of Inquiry was established by the province on February 1, 1977 to review the specific project and the more general issue of the desirability of future expansion of the uranium industry. The Inquiry recommended that both the Cluff Lake project and the expansion of the uranium industry in northern Saskatchewan be allowed to proceed subject to recommendations concerning such factors as health and safety of workers and distribution of economic benefits.

TABLE 1.6
URANIUM EXPLORATION EXPENDITURES IN CANADA BY
PROVINCE OR TERRITORY, 1978 AND 1979
(\$000,000)

	1978	1979	1980
Saskatchewan	43.6	70.5	77.2
Northwest Territories	17.0	26.4	29.1
Quebec	7.4	7.0	6.4
Newfoundland	2.8	6.8	3.7
British Columbia	7.0	3.9	0.6
Nova Scotia	2.4	3.8	4.5
Yukon Territory	1.0	2.7	1.3
New Brunswick	1.2	2.3	1.4
Ontario	2.3	2.1	1.7
Alberta	1.1	1.6	1.0
Manitoba	0.2	0.6	1.1
Unspecified	<u>4.0</u>	<u>1.8</u>	<u>0.3</u>
TOTAL	90.0	129.5	128.3

SOURCE: Uranium in Canada, op. cit.

The Saskatchewan government in a formal response to the Cluff Lake Inquiry¹⁶ agreed in principle with the development of Phase I of the Cluff Lake project and the expansion of uranium mining in Saskatchewan. Since that time the proposed Key Lake mine and mill has also received government approval in principle. The province is currently reviewing the Cluff Lake and the subsequent Key Lake Inquiry recommendations regarding further uranium developments. Saskatchewan now is particularly concerned with the orderly development of the industry, and more specifically, minimization of the historical boom and bust cycle.

Ontario has been the largest producer of uranium in Canada for 25 years. As indicated earlier, expansion of existing underground operations is underway in that province. In May, 1979 the Ontario Environmental Assessment Board, which reviewed the plans for expansion, concluded that it could be carried out in an environmentally acceptable manner. The Ontario Ministry of Environment has supported this view subject to extensive and regular monitoring of the developments and further research into the problem of long-term waste disposal.

A formal response by the Ontario government to the findings of these two agencies will be released shortly. It is expected, however, that Elliot Lake expansion will be approved, subject to a number of terms and conditions dealing with environmental and safety concerns.¹⁷

On May 29, 1980, the Government of Newfoundland and Labrador announced that it had accepted the recommendation of the provincially appointed Environmental Assessment Board that a development licence for the Brinex Kitts-Michelin project be withheld until safe disposal of mine and mill radioactive wastes could be satisfactorily demonstrated. This decision was specific to the project and the government emphasized that once such technical problems could be satisfactorily resolved uranium mining could proceed in the future. However, prior to the Newfoundland government decision, Brinex decided not to proceed with the project because of the depressed market situation.

Footnotes

¹ESI Resources Limited in Calgary, Alberta, a wholly-owned subsidiary of Earth Sciences Incorporated of Golden, Colorado, began commercial recovery of uranium from imported phosphate rock in 1980.

²Report of the Royal Commission of Inquiry into Uranium Mining, Province of British Columbia, D. V. Bates, Chairman, October 1980.

³General definitions of these categories, proceeding from more to less assured, are as follows:

- (a) Measured - Size, shape and mineral content have been well established by intensive sampling.
- (b) Indicated - Grade and outline of ore body based partly on sampling and inspection and partly on projection for a reasonable distance in light of other geological evidence.
- (c) Inferred - Quantitative estimates based largely on broad knowledge of geological character of the deposit rather than samples or direct measurements.
- (d) Prognosticated - Undiscovered uranium believed to be associated with already identified deposits.

⁴Uranium in Canada: 1979 Assessment of Supply and Requirements, Energy, Mines & Resources Canada, September 1980.

⁵Uranium in Canada, op. cit.

⁶Uranium - Resources, Production and Demand, OECD Paris, December 1979.

⁷Equivalent to Canada's "measured and indicated" resources, i.e., resources mineable up to prices of \$130/kg or costs of \$80/kg.

⁸Includes Canada's "inferred and prognosticated" i.e., resources mineable up to prices of \$200/kg or costs of \$130/kg.

⁹This section relies heavily on the following sources: The Uranium Industry in Canada, O.J.C. Runnalls, Energy, Mines and Resources Canada, April 1977; Market Opportunities for Canadian Uranium, R. M. Williams, Energy, Mines and Resources Canada, October 1979; Markets for Canadian Uranium, Proceedings of Seminar sponsored by the Canadian Energy Research Institute, October 1979, Calgary, Alberta.

¹⁰Eldorado had begun production of radium and silver at this deposit in 1933. The major constituent of the ore, uranium, had no foreseeable use at that time and was stockpiled as yellowcake at Port Hope.

¹¹The most important of which was restriction on foreign uranium that could be enriched in the U.S.

¹²This arrangement also excluded France, South Africa, Australia and Canada.

¹³Total production in 1980 was 7,145 tonnes.

¹⁴The limit is defined as 0.05 percent uranium in isolated samples and 0.01 percent at exploration sites, developed ore bodies and producing mines.

¹⁵For example, recommendations included establishment of a statutory requirement for public hearings for uranium mining and the assumption of full responsibility for standard setting and enforcement by the Province of British Columbia.

¹⁶The Saskatchewan Government Response to the Cluff Lake Board of Inquiry Report, Government of Saskatchewan, June 1978.

¹⁷Personal communication with staff of Ontario's Ministry of Environment and Environmental Assessment Board.

Chapter 2

FORECAST OF FUTURE URANIUM INDUSTRY ACTIVITY IN CANADA

2.1 Introduction

In order to estimate the economic impacts associated with the growth of the Canadian uranium industry, a forecast of future increases in uranium production by area (Saskatchewan, Ontario, other provinces) and mining method (underground and open pit) is required.

Such a breakdown is necessary to reflect important differences in cost structure which will affect the nature and magnitude of impacts in Canada.

Uranium production forecasts by area and mining method presented in this chapter are based on several recently completed demand and production capability studies¹ as well as our own and other analyses of these reports. Factors which affect the ability of producers to meet these demands are also considered.

A forecast period of 20 years 1981-2000 was chosen for this study for two reasons:

- Uncertainties regarding uranium requirements result in an extremely wide variance of possible demand scenarios beyond the year 2000.
- Existing forecasts of uranium requirements are more readily available for this period.

2.2 Demand for Canadian Uranium

Future growth in demand will depend entirely on the increase in installed nuclear power generating capacity in Canada and throughout the world.

2.2.1 Domestic Requirements

The Ministry of Energy, Mines and Resources, Uranium and Nuclear Energy Branch, has undertaken a forecast of

domestic uranium requirements based on projections of installed reactor capacity in Canada. This exercise is part of ongoing federal government assessment of domestic uranium needs and the allocation of these requirements among domestic producers.

A recent forecast of domestic reactor requirements (April 1980), based on low and high projections of installed reactor capacity, is presented below for the period 1980-2000.²

TABLE 2.1
ANNUAL CANADIAN URANIUM REQUIREMENTS^a
SELECTED YEARS 1980-2000
(tonnes)

	Low	High
1980 (estimated actual)	1,000	
1985	1,500	1,600
1990	2,000	2,600
1995	2,800	3,600
2000	3,400	4,700

^aBased on low and high installed nuclear capacity projections totalling 25,000 MW and 35,000 MW, respectively, by the year 2000.

SOURCE: Uranium in Canada: 1979 Assessment of Supply and Requirements, op. cit.

Ontario Hydro accounts for approximately 90 percent of uranium demand in Canada and the above requirement forecast is very similar to Hydro's projections of its own needs when other smaller users are taken into account.³

2.2.2 Export Requirements

Export markets have been in the past, and will continue to be, the major impetus for growth in Canada's

uranium industry. A major study on the long-term growth of nuclear power and uranium demand for the non-Communist world was carried out by the International Nuclear Fuel Cycle Evaluation (INFCE) Group under the auspices of the International Atomic Energy Agency (IAEA) in January 1980.⁴

The study estimated that world requirements could grow from a current level of about 30,000 tonnes per year to a level ranging from 130,000 tonnes to 160,000 tonnes per year by the year 2000, assuming a high rate of nuclear power growth. Assuming a lower rate of growth, world uranium requirements are estimated to range from 90,000 to 110,000 tonnes per year by the year 2000.

The divergence between high and low projections is due to varying assumptions about such factors as nuclear power growth and the mix of reactor types (which have different uranium feed requirements). Beyond the year 2000 the projections diverge even more, depending upon assumptions about the prevalence of fast breeder reactors (FBR's) which require negligible amounts of uranium after start-up.

The INFCE study is now regarded as a very optimistic forecast of nuclear energy growth and uranium requirements particularly beyond the year 1990.⁵

The Uranium Institute, a London-based research group, noted in its report on uranium supply and demand⁶ to its 5th Annual Symposium in September, 1980 that total reactor capacity commitments to 1990 and 1995 were already 10 and 35 percent, respectively, below INFCE's low projections for those years. The number of new reactor orders in non-Communist countries has dropped sharply since 1973. Cancellations are increasing and have outnumbered new orders since 1978.

The Uranium Institute projected non-Communist uranium requirements to 1995 based on the needs of operating and committed reactors only (low) and committed and uncommitted reactors (high). This forecast, along with our own extrapolation of the Institute's projection to 2000 based on its relationship in earlier years to the INFCE forecast, is presented in Table 2.2.

TABLE 2.2
URANIUM INSTITUTE FORECAST OF
NON-COMMUNIST URANIUM DEMAND^a
SELECTED YEARS 1980-2000
(tonnes)

	Low ^b	High ^c
1980 (actual)	30,000	
1985	45,000	45,000
1990	55,000	75,000
1995	55,000	90,000
2000 ^d	55,000	110,000

^aIncludes Canadian domestic requirements.

^bOperating and committed reactors.

^cCommitted and forecast of presently uncommitted reactors. The Uranium Institute's 'high' forecast is roughly equivalent to the INFCE 'low' forecast.

^dAuthor's own estimate.

SOURCE: Uranium Institute, Fifth Annual Symposium, September 1980, Figure 6, op. cit.

It should be noted that the Institute's projections encompassed the high and low scenarios of other groups (such as the U.S. Department of Energy) cited in their study, except for the more dated INFCE report.

Canada's share of the world uranium market in recent years has averaged roughly 15 percent, second only to that of the U.S. However, Australia and South Africa, on the basis of large reserves of relatively low-cost uranium, are expected to become increasingly important suppliers to the world market. As a result, Canada's share may well fall over the next 20 years, depending on a number of environmental, political and economic factors.

Some indication of Canada's future position in world uranium markets is given by its share of 'low cost'⁷ reasonably assured resources of uranium, estimated at 12 percent in the most recent IAEA assessment of world uranium supply.⁸

This estimate ranks Canada fourth as a world supplier, behind the U.S., Australia and South Africa.

Another indication of Canada's future market position is the IAEA's (INFCE Working Group) latest projection of maximum attainable world output of uranium by country of origin.⁹ This forecast includes 'high cost' uranium (i.e., mineable at costs up to approximately \$200/kg and incorporates similar projections from individual producing countries, including Canada.¹⁰ On the basis of maximum attainable output, Canada's market share gradually declines to approximately 11 percent by the year 2000.

Based on the foregoing discussion, it would appear that a decline in Canada's share of the world markets is quite possible. On the other hand, as the following excerpt from EMR's Uranium in Canada report indicates, there is still some expectation that Canada can maintain its current share.

As illustrated by current estimates of Canada's speculative resources, there is considerable potential for new uranium discoveries. The realization of even part of this potential should provide the basis for sufficient additional production centres to meet Canada's domestic requirements, as well as to maintain its position in the export market well into the next century.¹¹

For purposes of this analysis both a high-market-share assumption of 15 percent and a low-market-share assumption--with Canada's share falling to 12 percent by 1990 were used.

These assumptions, and the world demand scenario of the Uranium Institute were the basis of the forecast range for Canadian uranium export volumes which is summarized in Table 2.3.

TABLE 2.3
PROJECTED EXPORTS OF CANADIAN URANIUM^a
SELECTED YEARS 1980-2000
(tonnes)

	Low World Demand		High World Demand	
	A ^b	B ^c	A ^b	B ^c
1980 (estimated actual)			5,370	
1985	6,525	6,525	6,525	6,525
1990	6,360	7,950	8,690	10,860
1995	6,265	7,830	10,370	12,960
2000	6,190	7,740	12,635	15,795

^aCanadian domestic requirements have been deleted.

^bBased on Canadian market share falling to 12% by 1990.

^cBased on high Canadian market share of 15%.

The above table indicates a very wide dispersion of forecast export volumes. By the year 2000, low and high forecasts differ by a factor of 2.5. However, examination of uranium projects already committed to production and Energy, Mines and Resources Canada projections of maximum attainable production¹² in Canada suggest that the extreme low and high forecasts can be reasonably eliminated from further consideration.

2.2.3 Total Uranium Demand Forecast

Addition of domestic and export requirements¹³ yielded the following forecast of total Canadian uranium demand. (See Table 2.4).

TABLE 2.4
FORECAST OF DEMAND FOR CANADIAN URANIUM
SELECTED YEARS 1980-2000
(tonnes)

	Low	High	Maximum Attainable Production ^a
1980 (actual)		7,000	7,000
1985	8,025	8,125	14,400
1990	9,950	11,290	15,500
1995	10,630	13,970	15,400
2000	11,140	17,335	12,500

^aMonitoring Canada's Uranium Supply, Energy, Mines and Resources Canada, op. cit.

The above forecast suggests that the demand for Canadian uranium will grow relatively slowly over the next 20 years. In the 'low' scenario the average annual growth rate is 2.4 percent; in the 'high' case it is 4.6 percent per year. Based on production capability, the forecasts might appear conservative. However, given the expected sharply reduced growth rate in nuclear reactor capacity and resulting soft markets, the forecasts are not considered unrealistic.

The 'high' demand forecast exceeds maximum attainable production by 1995-2000. Maximum attainable production is based on the development of resources associated with known deposits. Therefore, while the 'high' forecast may be optimistic, it could be attained if further non-associated resources are discovered and developed.

2.2.4 Forecast of Uranium Production by Province

The breakdown of the uranium demand projections by province in Table 2.5 was estimated on the basis of planned and committed projects and EMR's provincial distribution of

projected maximum attainable production. This same percentage distribution was used for both the 'low' and 'high' projections.

TABLE 2.5
FORECAST OF URANIUM PRODUCTION BY PROVINCE
SELECTED YEARS 1980-2000^a
(tonnes)

		Ont.	Share (%)	Sask. ^b	Share (%)	Other Prov.	Share (%)	Total
1980 (actual) ^c		4725	(67)	2325	(33)	-	-	7050
1985	Low	4655		3370		-	-	8025
	High	4715	(58)	3410	(42)	-	-	8125
1990	Low	4675		4875		400		9950
	High	5305	(47)	5530	(49)	455	(4)	11290
1995	Low	5315		4785		530		10630
	High	6985	(50)	6285	(45)	700	(5)	13970
2000	Low	6125		4455		560		11140
	High	9535	(55)	6935	(40)	875	(5)	17335

^aDiscrepancies between percentage and absolute estimates are due to rounding error.

^bIncludes 400 tonnes/year throughout the forecast period from Eldorado's underground mine in Saskatchewan.

^cTotal Annual Production = Annual Shipments plus Change in Inventories.

The above breakdown should only be considered as a rough indication of the provincial distribution of uranium production. It is assumed, based on knowledge concerning planned and potential developments, that future mine development in Ontario will be underground, whereas in Saskatchewan and other provinces (such as B.C. and Newfoundland) it will be mostly open pit. The increasing share of production allocated to Ontario after 1990 reflects the importance of the Elliot Lake area in terms of longer term prognosticated resource development (i.e., undiscovered resources believed to be associated with known deposits).

2.3 Supply Constraints

Given the potential availability of Canadian uranium, it is clear that the primary constraint on future increases in production is market demand. Nevertheless, there are potential constraints on the supply side, all of which affect costs and which could possibly prevent production from reaching forecast levels. A brief discussion of these constraints follows.

2.3.1 Transportation and Townsite Infrastructure

Uranium is a low-volume, high-value product. Unlike coal, for example, forecast growth of uranium mining output would not require substantial additional capital investment in rail or port transportation facilities. Therefore, potential environmental and financial concerns associated with additional transportation requirements do not pose significant obstacles to further development of the uranium industry.

With regard to townsite infrastructure, proposed expansion of Denison and Rio Algom at Elliot Lake will require substantial expenditures on additional housing and related services, to which the mining companies will contribute significantly.

There is currently a trend among new Saskatchewan mines towards fly-in, rotational, manning programs. This is based on the apparently successful experience with such a program at Gulf Minerals' Rabbit Lake operation. It has reduced labour turnover rates substantially although this may be offset by additional labour, overtime and air travel costs.

New or expanded production in both Ontario and Saskatchewan will require significant expenditures for either townsite infrastructure or fly-in programs--increasing the break-even supply price of uranium.

2.3.2 Labour Requirements

To attain annual production levels of some 11-17 thousand tonnes of uranium by the year 2000 will require roughly 7,500 to 11,700 uranium mining workers in Canada, or

up to double current levels. This could pose difficulties, particularly for underground operations (some of which have already encountered recruiting problems) and for mines in western Canada if large energy projects such as oil sands development in Alberta, go ahead. Increased relative wages and associated costs can overcome these problems but they will increase the cost of uranium.

2.3.3 Environmental/Regulatory Costs

All uranium mine proposals are subject to detailed environmental impact assessments and regulatory approval is conditional upon compliance with existing environmental and health standards. Proponents are generally held financially responsible for measures deemed necessary to prevent, reduce or offset environmental effects of all aspects and phases of the development.¹⁴

The mitigation of environmental impacts will add to the supply price of uranium. Secor, Inc. estimated that the primary uranium industry (mining, milling) in Canada spends approximately \$43 million per year in order to comply with imposed and voluntary environmental and health standards and regulations.¹⁵ This translates into an average annual cost of about \$6.10/kg.

As the number of uranium mines and experience with environmental effects has increased, standards and associated costs have become increasingly stringent, and this trend may continue, particularly with regard to tailings treatment and mine/mill reclamation.

2.4 Price Forecast

In light of the above discussion regarding supply constraints, most of which have the potential for increasing the supply price of uranium, it can be seen that achievement of high production scenarios will require strong demand in terms of both volume and prices.

Uranium prices experienced a sharp decline in 1981. The world price, which peaked at \$95 to \$110/kg in late 1979, has since fallen below \$75/kg. One of the main reasons for the uranium price decline has been excess supply. Electric utility companies (major consumers) both in the U.S. and

Canada, have been generating uranium supplies in excess of their requirements through their long-term contracts with mining companies. The slowdown in construction of nuclear reactors around the world (and particularly in the U.S.) has contributed to the problem.

Comparison of the INFCE maximum obtainable supply and requirement projections indicated a potential surplus of uranium supply well into the 1990's. The subsequent Uranium Institute Study suggests that this potential surplus may even be more pronounced than that indicated by INFCE. Comparison of EMR's projection of maximum attainable production in Canada with our 'high' forecast of demand, and anticipated developments in Australia and South Africa, provide additional indication of the potential for continued imbalance in world uranium markets.

International political developments can rapidly change the uranium market outlook. However, even an immediate resurgence of nuclear plant orders would not significantly alter the short-term market situation, since the lead times involved mean that few such plants would be operating before 1990.

In view of the above, our 'most probable' price forecast is as follows:

- There may be some decline in real uranium prices¹⁶ until 1985, followed by a gradual recovery to 1980 real levels of about \$100/kg, or about \$45/lb., by 1990.
- From 1990 to 2000 it is assumed that prices will fluctuate as they have historically but, on average, will remain constant in real terms at the \$100/kg level, with some potential for small real price increases.

This price scenario may be considered conservative. For example, it corresponds to the 'low' case of a recent internal EMR projection to 1990. Also, some producers expect an earlier upturn in demand and prices than assumed above. However, in light of recent events and current perspectives, such as the forecast relatively low growth in demand, it is not, in our view, unrealistic.

As shown in Chapter 1, the uranium industry in Canada has had a history of price and output fluctuation. Current market conditions and the possibility of large increases in Canadian production capacity suggest the potential for repetition of this cycle. The implication of a 'low' price scenario for the magnitude and distribution of the economic impacts of the uranium industry is examined in Chapters 3 and 4.

Footnotes

¹Fuel and Heavy Water Availability, Report of International Nuclear Fuel Cycle Evaluation (INFCE) Working Group of the International Atomic Energy Agency, Vienna, March 1980 (projections based on 1979 data); The Balance of Supply and Demand: A Reassessment, P. Darmayan, presented to the 5th Annual Symposium of the Uranium Institute, London, September 1980; Uranium and Nuclear Energy Branch of Energy, Mines and Resources Canada, projections of uranium production capability in Canada.

²Since the time this analysis was undertaken more recent forecasts of domestic and world demand for uranium have been published. These forecasts indicate a slightly lower range of requirements than are assumed in this study.

³Based on discussion with officials in Ontario Hydro's Fuel Supply Department.

⁴Fuel and Heavy Water Availability, op. cit.

⁵Uranium demand to 1990 is more accurately estimated since forecasts can be based upon requirements of reactors in operation and under construction and since it is generally accepted that FBR's will not be introduced in significant numbers by this time.

⁶The Balance of Supply and Demand: A Reassessment, op. cit.

⁷This is equivalent to Canada's low price reserve categories, i.e., mineable up to a price of \$130/kg U. Canada's share of 'high cost' resources is much greater (see Chapter 2) but this category is not as valid an indicator of future production levels.

⁸Uranium - Resources, Production and Demand, NEA/IAEA, December 1979. This projection assumes no manpower, equipment, financing, demand or other constraints on uranium production.

⁹Uranium - Resources, Production and Demand, op. cit.

¹⁰See Monitoring Canada's Uranium Supply, Energy, Mines and Resources Canada, Report ER80-5E.

¹¹op. cit., p. 27.

¹²Maximum attainable production from resources associated with known deposits (i.e., existing and planned production centres) assuming no demand, supply or regulatory constraints. See Monitoring Canada's Uranium Supply, op. cit.

¹³The low domestic forecast was added to the low export forecasts (case B), and the high domestic to the high export forecast (case A).

¹⁴One area of uncertainty, with regard to uranium mining in particular, is the financial responsibility for the very long-term impacts of mine and mill waste treatment or storage.

¹⁵Estimating the Costs of AECB Regulations, Secor, Inc. for the Atomic Energy Control Board, April 1981. The above estimate excludes industry (mining/milling) capital investment in radiation safety equipment of about \$122 million.

¹⁶Comprised of a weighted average of 'spot' prices and contract prices, the weights being approximately 25 percent and 75 percent, respectively.

Chapter 3

INPUT STRUCTURE OF URANIUM MINE DEVELOPMENT AND OPERATIONS

3.1 Introduction

The economic impacts associated with the uranium industry in Canada depend on the magnitude and nature of materials, equipment, services and labour inputs required for uranium mining and related activity. In this chapter, estimates of the input structure for developing and operating uranium mines and mills, by type and area of mine, are presented. These costs comprise the direct impacts of the uranium industry and form the basis for the total direct plus indirect impact analysis which follows.

It should be noted that the input structures summarized below are by necessity generalized and apply to average or 'typical' conditions. Per unit output¹ costs, and cost breakdowns can vary for specific operations depending upon such factors as scale of production, ore grade, location and accessibility. The figures below were developed for purposes of estimating impacts of overall growth in the industry and should not be interpreted as reflective of all mines in each region. Cost breakdowns are not available for uranium exploration. However, an indication of the economic impacts of exploration activity is provided in Chapter 4 on the basis of Statistics Canada's input vectors for "Services Incidental to Mining."

3.2 Input Structure for Open Pit Uranium Mining in Northern Saskatchewan²

3.2.1 Capital Requirements

On the basis of uranium company submissions prepared by consultants for Saskatchewan public inquiries into the Cluff Lake and Key Lake projects, cost studies prepared for the federal Department of Energy, Mines and Resources Canada, as well as discussions with industry and government

officials, it is estimated that the capital cost of developing a 'typical' open pit uranium mine and mill is in the range of \$110/kg of annual uranium metal output.³ Construction labour accounts for about 22 percent of total mining and milling capital costs; equipment, materials and services accounts for the remaining 78 percent. It is estimated that the construction of an open pit mine and mill requires approximately 600 man-years per million kilograms of annual production capacity.⁴

3.2.2 Operating Requirements

A breakdown of material, service and labour costs, government revenues and gross operator profit margins per kilogram of open pit production is shown in Table 3.1. It is estimated that the 1980 typical f.o.b. mine/mill value of uranium is about \$100/kg.⁵ Of this, material and service costs account for about \$6.10/kg, labour costs \$5.50/kg, government revenue (including federal and provincial income tax and provincial royalties) \$50.30, and gross margin (including depreciation, interest on debt and return on equity) \$38.10. These estimates are based on impact studies submitted to the Cluff Lake and Key Lake inquiries as well as discussions with various industry and government officials.

TABLE 3.1

OPERATING COSTS AND REVENUES PER KILOGRAM OF
URANIUM OUTPUT: SASKATCHEWAN OPEN PIT,
MINE AND MILL OPERATION

	\$1980/kg
Material & Service Costs	6.10
Gross (pre-tax) Labour Cost	5.50
Government Revenue	
- Corporate Income Tax	
Federal	15.30
Provincial	5.20
- Provincial Royalty	29.80
Gross Operator Margin ^a	38.10
TOTAL UNIT VALUE (f.o.b. Mill)	100.00

^aIncludes depreciation, interest payments and after-tax profits.

SOURCES: InterGroup Consulting Economists, op. cit., Kilborn Engineering, op. cit., and Energy, Mines and Resources Canada, and industry representatives.

Aside from project-specific economic conditions such as ore grade, etc., two factors affect the Saskatchewan open pit cost breakdowns. One is the extent of participation of the Saskatchewan Mineral Development Corporation (SMDC) in any particular project. As a Crown corporation, it is not subject to corporate income tax. Thus, the greater its participation, the lower the proportion of income tax and the higher the share of provincial royalties and operator gross margin.

The cost breakdown given in Table 3.1 is based essentially on two projects--Cluff Lake in which SMDC has a 20 percent equity share, and Key Lake of which the SMDC owns 50 percent. In view of provincial legislation which enables the SMDC to acquire up to 50 percent equity in any future uranium development, the above breakdown may understate the relative importance of provincial royalties and operator gross margin over the forecast period.

The other major factor affecting the cost breakdown for Saskatchewan (which will also apply for Ontario) is the price assumption. Royalties in both of these provinces are related directly to profit margins which, in turn, depend upon the product selling price.⁶ Use of 1980 prices is probably optimistic for the short term in light of current market conditions. However, over the 20-year forecast period, price levels are expected to recover and stabilize in real terms.

To provide an indication of the impact of lower price levels on the operating cost structure of Saskatchewan open pit mining, the following breakdown was estimated on the basis of price sensitivity analyses for the Cluff Lake and Key Lake projects.⁷ It assumes a 30 percent drop in the constant price level of \$100/kg (about \$45/lb.) to \$70/kg (about \$32/lb.) over the forecast period.

TABLE 3.2

OPERATING COSTS AND REVENUE PER KILOGRAM OF
URANIUM OUTPUT - SASKATCHEWAN OPEN PIT
MINE AND MILL: LOW PRICE ASSUMPTION

	\$1980/kg	Percent Composition
Material & Service Costs	5.81	8.3
Gross (pre-tax) Labour Cost	4.13	5.9
Government Revenue		
- Corporate Income Tax		
Federal	12.32	17.6
Provincial	4.48	6.4
- Provincial Royalty	16.10	23.0
Gross Operator Margin	27.16	38.8
TOTAL UNIT VALUE (f.o.b. Mill)	70.00	100.0

The cost breakdown for a 'low' price assumption shows that provincial royalties fall to about 23 percent of the total revenue per unit of output from almost 30 percent in the 'most probable' price scenario, while all other categories maintain or increase their share. This reflects

the steeply progressive nature of the Saskatchewan royalty system.

A breakdown of operating labour requirements, by broad occupation category, is shown in Table 3.3. It is estimated that for Saskatchewan open pit mining and milling, an average of about 225 workers (including supervision and head office administration) is required per million kilograms of annual output.⁸ Almost 75 percent of these are hourly wage earners, with equipment operators and skilled mining and milling workers being the most important wage earner categories.

TABLE 3.3
AVERAGE OPERATING LABOUR REQUIREMENTS FOR SASKATCHEWAN
OPEN PIT URANIUM MINE AND MILL

	Number/Million Kilograms of Output	Percent Composition
Salaried Staff	60	26.9
Hourly Wage Earners	165	73.1
Mobile Equipment Operators	44	19.4
Other Skilled Tradesmen	84	37.3
Labourers and Helpers	37	16.4
TOTAL	225	100.0

SOURCES: Kilborn Engineering, op. cit, and InterGroup Consultants, op. cit.

3.3 Input Structure for Underground Uranium Mining in Ontario

3.3.1 Capital Requirements

Based on estimates by Kilborn Engineering and Energy, Mines and Resources (CANMET), the capital cost of

developing a 'typical' underground uranium mine and mill in Ontario in 1980 was estimated at approximately \$235/kg of annual output. The higher capital cost in Ontario versus Saskatchewan is due to two factors:

- the lower uranium content of Ontario deposits, requiring the mining and milling of greater volumes of ore
- the higher development cost inherent in an underground operation regardless of ore content

Approximately 25 percent of the mine/mill capital cost is accounted for by construction labour, with the remainder comprising equipment, materials and services.⁹ Labour requirements for the construction of a mill and underground mine are estimated at approximately 1470 man-years per million kilogram of annual production capacity.

3.3.2 Operating Requirements

Table 3.4 shows a breakdown of operating materials, service and labour costs, government revenues and gross operator margin per kilogram of Ontario uranium production. The breakdown is based on estimates by Kilborn Engineering, Wright Engineering and discussions with other industry and government officials.

It was assumed that the f.o.b. mine/mill value of uranium mined in Ontario is the same as that in Saskatchewan. Materials and services account for \$13.10/kg, labour costs \$22.00/kg, royalties and taxes \$36.90/kg and operator gross margin \$28.00/kg.

TABLE 3.4

OPERATING COSTS AND REVENUES PER KILOGRAM
OF URANIUM OUTPUT: AN ONTARIO
UNDERGROUND MINE AND MILL

	\$1980/kg
Material & Service Costs	13.10
Gross (pre-tax) Labour Cost	22.00
Government Revenue	
- Corporate Income Tax	
Federal	11.20
Provincial	3.80
- Provincial Royalty	21.90
Gross Operator Margin	28.00
TOTAL UNIT VALUE (f.o.b. Mill)	100.00

SOURCES: Kilborn and Wright Engineering, op. cit.

The discussion on pages 36-37 with respect to the effect of a 'low' price assumption on operating cost break-downs for Saskatchewan is generally valid here given that the Ontario mining royalty is also profit-based. However, the decline in the share of provincial royalties will not be as pronounced in Ontario because of the less progressive nature of its royalty structure. Present and future uranium mining activity in Ontario will likely be undertaken by the private sector and the qualifications concerning Crown participation and corporate income tax do not apply here.

A breakdown of operating labour requirements for Ontario underground uranium mining and milling is shown in Table 3.5. It is estimated that, on average, 1044 workers are required per million kilograms of uranium metal, approximately 5 times the labour/kilogram requirement of a Saskatchewan open pit mine and mill. The much greater labour requirement per kilogram for Ontario versus Saskatchewan is due to the lower uranium content of Ontario ores and to the fact that underground mining is a more labour-intensive method of extraction.

TABLE 3.5

AVERAGE OPERATING LABOUR REQUIREMENTS FOR
ONTARIO UNDERGROUND URANIUM MINE AND MILL

	Number/Million Kilograms of Output	Percent Composition
Salaried Staff	220	21.1
Hourly Wage Earners	824	78.9
Mobile Equipment Operators	81	7.8
Other Skilled Tradesmen	612	58.6
Labourers and Helpers	131	12.5
TOTAL	1044	100.0

SOURCES: Kilborn Engineering, op. cit., and InterGroup Consultants, op. cit.

3.4 Input Structure for Transportation and Townsite Infrastructure

Because uranium is a high-value, low-volume product, forecast volumes will not require significant investment in incremental port or rail capacity. Uranium is generally transported by truck from the mine site and construction of new access roads to connect with the existing network is usually required for new mines.

With regard to provisions for worker accommodation and transportation to the minesite, fly-in programs are being adopted by new Saskatchewan mines in place of new townsite development. This will require construction of air service facilities at or near the minesite.

In Ontario, where increased production will be primarily from expansion or rehabilitation of existing mines, significant additional investment in road access or air service facilities will not likely be required. Additional townsite development will be needed at Elliot Lake.

Scale and cost breakdowns for transportation and townsite infrastructure were not available. For this reason, the economic impact of these activities is not included in the estimates presented in the next chapter. In any event the economic impacts of complementary activities are not likely to be large in comparison with the total impacts of uranium exploration and mine construction and operation.

3.5 An Overview

In summary, the development costs of typical open pit and underground mines in 1980 are in the order of \$110 and \$235, respectively, per kilogram of annual uranium output. Construction labour intensity for open pit and underground mining is about 600 and 1470 man-years, respectively, per million kilograms of production capacity.

Total operating cost, excluding operator margin and government revenues is approximately \$11.60 for open pit and \$35.10/kg for underground. A 'low' price scenario would reduce government revenues as a proportion of total operating cost while other components, such as labour and materials, would become relatively more important. Operating labour requirements per kilogram are estimated at 225 and 1044 for open pit and underground, respectively.

The much higher per-unit costs and labour requirements of underground mining are due to the inherent nature of this mining method and much lower ore grades associated with it.

Footnotes

¹All per unit costs are in \$1980 (Canadian). The implied assumption is that there will be no real increase in capital or operating costs over the forecast period.

²Most uranium mining in Saskatchewan will likely use the open pit method. A small underground mine at Eldorado currently accounts for about 15 percent of Saskatchewan production, but as new mines come on stream in Saskatchewan, its share will fall to about 5-8 percent. Since specific data were not available for Eldorado, underground cost data developed for Ontario were used.

³See InterGroup Consulting Economists Ltd., Socio-Economic Impact: Cliff Lake Uranium Project and Economic Impact of the Key Lake Uranium Project in Saskatchewan; Wilborn Engineering Canadian Mining Costs: Uranium Mining Examples; Wright Engineers Capital and Operating Costs: Uranium Mining Examples; and E. G. Joe of CANMET, Energy, Mines and Resources Canada, Capital and Operating Costs for Uranium Milling in Canada.

⁴Estimated as the labour component of unit capital cost divided by an average wage of \$40,000 per man-year. (Source: InterGroup Consulting Economists, Key Lake Project op. cit.)

⁵Based on the per kilogram value of Canadian uranium shipments in 1980.

⁶The royalty structures in Saskatchewan and Ontario are as follows:

Saskatchewan

<u>Tax Rate</u>	<u>Operating Profit/ Capital Investment</u>
0%	15%
15%	15% - 25%
30%	25% - 45%
50%	45% +

Ontario

<u>Tax Rate</u>	<u>Mining Profit</u>
0%	\$ 0 - \$ 250,000
15%	\$ 250,000 - \$ 1,000,000
20%	\$ 1,000,000 - \$10,000,000
25%	\$10,000,000 - \$20,000,000
30%	Over \$20,000,000

⁷Socio-Economic Impact: Cluff Lake Uranium Project, op. cit., and Brief on Provincial Revenue Effects, presented to Key Lake Board of Inquiry by Saskatchewan Department of Minerals Resources, August 1980.

⁸Operations employment per kilogram is estimated on the basis of the labour cost estimate in Table 3.1 and an assumed annual average wage of \$24,400. This assumption was based on the average wage in Canadian mining and milling for 1980 (Source: Statistics Canada 72-002) adjusted for supplemental income associated with remote working conditions. Note that the assumed wage in construction is significantly higher than for operations because of greater overtime and camp allowances for construction workers.

⁹Based on estimates by Kilborn, op. cit., for mining and Energy, Mines and Resources Canada (CANMET), InterGroup Consulting, op. cit., for milling.

Chapter 4

ECONOMIC IMPACT ASSESSMENT

4.1 Introduction

Growth of Canada's uranium industry will have both direct and indirect effects on the provincial and national economies. Direct effects are the production, employment and income impacts generated within the uranium industry itself. They will result from the increase in demand for labour, material and equipment required for uranium exploration, development and mining. Indirect effects refer to the production, income and employment generated in other industries as a result of the linkages between the uranium industry and the rest of the economy.

In this chapter, the direct and indirect effects of forecast growth in the Canadian uranium industry are discussed. Estimates of the direct effects are based on the input structure of the various stages of uranium activity as described in the previous chapter. The analysis and estimates of the indirect effects are based on 'backward' linkages or relationships between uranium activity and other sectors in the economy supplying inputs to the uranium industry.

To estimate the backward linkage multiplier effects--that is, the effects on the industries which supply goods and services to the uranium industry and its workers, and the industries which supply them, and so on--Statistics Canada's latest (1974) inter-provincial input-output table was used. An input-output table is a detailed set of accounts which indicates the amount of every commodity used by every industry. The inter-provincial table also breaks down the inputs by provincial origin of supply. Given the input structure for uranium mining and mine development, the table can thus be used to trace, in effect, the derived demands on all other industries, by province, as well as for Canada as a whole.

Forward linkage impacts--that is the economic impact on industries which use milled uranium output (i.e., uranium refining and the domestic nuclear power industry)--are beyond the scope of this study. The impacts of complementary or sideways linkages such as townsites development are not estimated because of the lack of input cost data.

The final section of this chapter compares the direct and indirect impacts of the uranium industry in Canada with other selected extractive and energy industries.

4.2 Assessment of Direct and Backward Linkage Impacts Per Unit Output

Direct and backward linkage impacts represent the total derived demand effects of uranium mining and milling in Canada. The direct impacts constitute the first round effect; the indirect or backward linkage impacts constitute all subsequent round or multiplier effects.

It should be noted that the manner in which 'direct impact' is defined can affect the size of the income and employment multipliers. In this study, the direct--or first round effect--refers to income and employment generated solely within the uranium mining industry. In the case of capital expenditure impacts it therefore refers to construction employment and income. For mine operation impacts it refers to operating employment and income. This definition is one that is commonly used in industry impact studies.¹

An alternative way of measuring the first round effect would be to include all income and employment associated with the purchase of materials used directly in the industry. This measures the initial increase in final demand associated with the expansion of the industry. This definition has been used in literature on inter-industry analysis.² Because 'direct' is defined more broadly in this definition, the reported multipliers (total/direct) would have been smaller had we used it in this study. This is important to recognize when interpreting and comparing the multiplier results.

Capital or mine development expenditures and operating expenditures are described below. Mine impacts are

reported separately for Saskatchewan (open pit) and Ontario (underground) because of the marked difference in the cost characteristics and consequent impacts of the different types of operations.

Mine impact estimates are presented per 1000 tonnes of annual output (which in 1980 reflects \$100 million of annual revenues). In Section 4.3 the impact estimates for uranium mining and milling are multiplied by forecasts of uranium output to estimate the total effects of the industry on the economy over the next 20 years. The employment and income impacts of 1980 uranium exploration expenditures are also presented in Section 4.3.

4.1.1 Capital Expenditure Impacts--Saskatchewan

As discussed in Section 4.2 of this chapter, the capital cost of an open pit uranium mine in Saskatchewan is estimated to be \$110/kj of annual uranium metal output. Thus, the capital cost of a mine with the capacity to produce 1000 tonnes of output annually would be about \$110 million. As shown in Table 4.1, this would generate over \$24.2 million in direct labour income and approximately \$36 million of income in Saskatchewan indirectly. It is interesting to note that \$40 million of indirect income would be generated in Ontario and Quebec as a result of this capital expenditure, an amount greater than the indirect income in Saskatchewan itself. This is because Ontario and Quebec have the industrial infrastructure to produce and supply much of the needed material and equipment while Saskatchewan does not. Canada as a whole would realize about \$101 million in indirect income and \$125 million in total. The national income multiplier is 5.0 compared to 2.5 for Saskatchewan alone.

In terms of employment the capital expenditure required for 1000 tonnes of production capacity would generate some 600 man-years of direct employment. In Saskatchewan, another 1200 man-years of employment would be generated indirectly for a total of 1800. The indirect employment impact for Ontario and Quebec is about 1670 man-years which, like the indirect income impact, is greater than in Saskatchewan. This explains the high national employment multiplier of 6.9 compared to 3.0 for Saskatchewan.

TABLE 4.1
 INSTALLED DIRECT AND INDIRECT ECONOMIC IMPACTS--
 URANIUM MINE AND MILL DEVELOPMENT--SASKATCHEWAN

INCOME IMPACTS: ^a	(\$1980 x 10 ⁶)				Canada as a whole		
	Saskatchewan	Western	Ontario and Quebec	Atlantic			
Direct Income	24.2	24.2					24.2
Indirect Income:							
Household ^b	26.2	19.3	29.1	.3			67.7
Surplus ^c	10.1	18.8	11.9	2.3			33.0
Total	16.3	58.1	40.0	2.6			100.7
Total Income:	60.5	82.3	40.0	2.6			174.9
Multiplier (Total/Direct)	2.5	3.4	n.d.	n.d.			5.0
EMPLOYMENT IMPACTS:							
	Saskatchewan	Western	Ontario and Quebec	Atlantic			Canada as a whole
Direct ^d	600	600					600
Indirect	1,000	1,920	1,870	30			3,820
Total	1,600	2,520	1,870	30			4,420
Multiplier (Total/Direct)	1.0	4.2	n.d.	n.d.			6.9

^aBased on a cost of \$110 x 10⁶/million kilograms.

^bIncludes wages, salaries and other supplementary

^cIncludes all non-household income

^dBased on an average annual wage of \$40,000.

4.2.2 Capital Expenditure Impacts--Ontario

A comparable uranium mine in Ontario with a 1000 tonne annual output capacity would require a capital expenditure of about \$235 million, more than twice the cost of a mine in Saskatchewan. This is due to two factors. Firstly, the mine in Ontario would be an underground mine with its inherent higher costs relative to an open-pit mine. Secondly, the uranium mined in Saskatchewan is of a significantly higher grade than that mined in Ontario.

As shown in Table 4.2, the direct income impact in Ontario would be about \$59 million and, as a result of inter-industry purchases of materials and the responding of household income, an additional \$153 million would be generated in Ontario indirectly. Most of the indirect income impact accrues to Ontario, some 77 percent of the national indirect income impact of \$199 million. Again, this is due to Ontario's ability to supply its own industrial requirements. This explains why Ontario has a much higher income multiplier, 3.6, compared to Saskatchewan's 2.5.

In terms of employment, capital spending would generate almost 1500 man-years of employment directly and an additional 6000 jobs indirectly in Ontario. Canada as a whole would feel a total impact of about 9100 man-years of employment. The Ontario employment multiplier is 5.1, and the national multiplier is 6.2.

4.2.3 Mine Operating Impacts--Saskatchewan

The mine operating impacts for both Saskatchewan and Ontario are based on the input requirements to produce 1000 tonnes of uranium. It should be noted that these impacts are qualitatively different from the capital expenditure impacts in that they are annual, ongoing impacts that would last for the duration of the mine.

The production of 1000 tonnes of uranium in Saskatchewan would entail revenues of \$100 million, but material and service expenditures of only some \$6.1 million. The direct income³ impacts are very large--some \$93.9 million--for the most part because of royalties and corporate earnings which account for almost 70 percent of total revenues.

As shown in Table 4.3, the indirect income impacts on the other hand are quite small--\$3.5 million in Saskatchewan and \$10.2 million for Canada as a whole. The reason that the indirect effects (and multipliers) are so small is because of the relatively small proportion of revenues that are accounted for by material and service expenditures and labour incomes. It is these components of total revenues which are responsible for the backward linkage or derived demand effects.

In terms of employment, mine operations would generate 225 jobs directly and 110 jobs indirectly in Saskatchewan. For Canada as a whole 360 jobs would be generated indirectly. Again, as with the capital expenditure impacts, much of the indirect effects which are generated accrue to Ontario and Quebec.

4.2.4 Mine Operating Impacts--Ontario

As shown in Table 4.4, the production of 1000 tonnes of uranium in Ontario would directly generate \$87 million in income. As in Saskatchewan, this is a large component of total revenues, though in this case the labour, as opposed to government and corporate share of direct income, is significantly higher.

Because of the higher direct labour income, and higher material and service expenditures, the indirect impacts per 1000 kilograms of production are much higher for Ontario than Saskatchewan operations. Approximately \$22 million in income is generated indirectly in Ontario; \$30 million for Canada as a whole.

Again, as with the Ontario mine capital expenditure impacts, most of the indirect effects are felt in Ontario.

The employment impacts of Ontario mine operations are considerably higher than in Saskatchewan. For 1000 tonnes of output, over 1000 jobs would be generated directly and 840 jobs generated indirectly in Ontario. Some 1080 jobs would be generated indirectly in Canada as a whole.

TABLE 4.3
DETAILED DIRECT AND INDIRECT ECONOMIC IMPACTS--
URANIUM MINE OPERATION IN SASKATCHEWAN

INCOME IMPACTS: ^a (\$1980 x 10 ⁶)	Saskatchewan	Western	Ontario and Quebec	Atlantic	Canada as a whole
Direct income: ^b	93.9	93.9			93.9
Indirect income:					
Household inc	2.1	3.7	2.6		8.4
Supplier ^d	1.4	2.7	1.1		5.2
Total	3.5	6.4	3.7		10.2
Total income:	97.4	100.3	3.7		104.1
Multiplier (Total/Direct)	1.04	1.07	n.a.		1.11
EMPLOYMENT IMPACTS:					
Direct ^e	225	245			225
Indirect	110	200	160		360
Total	335	445	160		580
Multiplier (Total/Direct)	1.5	1.9	n.a.		2.6

^aAnnual cost: \$79.4 x 10⁶ million kilograms
^bIncludes wages, salaries and other supplementary labour income.
^cIncludes all non-household income.
^dBased on an average annual wage of \$24,444.

TABLE 4.4
DETAILED DIRECT AND INDIRECT ECONOMIC IMPACTS--
URANIUM MINE OPERATION IN ONTARIO

INCOME IMPACTS: ^a (\$1980 x 10 ⁶)	Ontario	Ontario and Quebec	Western	Atlantic	Canada as a whole
Direct Income: ^b	86.9	86.9			86.9
Indirect Income:					
Households ^c	14.7	17.6	1.1	.3	19.0
Surplus ^d	7.4	8.8	1.0	.1	10.6
Total	22.1	26.4	2.9	.4	29.6
Total Income:	109.0	113.3	2.9	.4	116.5
Multiplier (Total/Direct)	1.25	1.3	n.a.	n.a.	1.34
EMPLOYMENT IMPACTS:	Ontario	Ontario and Quebec	Western	Atlantic	Canada as a whole
Direct ^e	1044	1044			1044
Indirect	840	1010	50	20	1080
Total	1880	2050	50	20	2120
Multiplier (Total/Direct)	1.8	2.0	n.a.	n.a.	2.0

^aAnnual cost: \$85.0 x 10⁶/million kilograms.
^bIncludes direct labour income, government royalties and other operating surplus.
^cIncludes wages, salaries and other supplementary labour income.
^dIncludes investment income.
^eBased on an average annual wage of \$21.071.

4.3 Direct and Backward Linkage Impacts Associated with Present and Future Uranium Activity in Canada

In the previous section, the direct and backward linkage impacts associated with uranium mining and milling were assessed per 1000 tonnes of output. In this section, these impacts are multiplied by the forecast of uranium production to estimate the total direct and backward linkage impacts that will be generated by future growth of the uranium industry in Canada. 'High' and 'low' estimates are developed in accord with the 'high' and 'low' production forecasts developed in Chapter 3. The impacts of actual 1980 uranium exploration expenditures in Canada are also presented in this section.

4.3.1 Exploration

Exploration impacts are conceptually similar to those described for the uranium industry as a whole in Section 4.1 of this chapter. Direct impacts constitute first round effects; the indirect or backward linkage impacts constitute all subsequent round or multiplier effects. Multiplier effects are estimated on the basis of Statistics Canada's 1974 inter-provincial input-output table.

Independent and up-to-date cost breakdowns for exploration were not available. Therefore the cost structure of the 'Services Incidental to Mining' industry as provided by Statistics Canada's input-output model was used as a proxy to provide an indication of the impacts of this component of the uranium industry.

On this basis (as shown in Table 4.5), it is estimated that exploration expenditures of \$128 million in 1980 generated direct income of \$96.4 million and indirect income of \$82.3 million in Canada. Direct employment generated in Canada by these expenditures amounted to about 3000 jobs with a further 3200 created indirectly. National income and employment multipliers for uranium exploration are 1.9 and 2.1, respectively.

With regard to the regional distribution of impacts, Saskatchewan, the Yukon and N.W.T. account for about 78 per cent of direct impacts, reflecting the high levels of exploration activity in these regions. On the other hand

70 percent of indirect impacts accrues to 'Other Provinces', primarily Ontario and Quebec. This is due, not so much because of direct exploration activity, but to the spillover effect into Ontario and Quebec of exploration expenditures made elsewhere.

TABLE 4.5

DIRECT AND INDIRECT ECONOMIC IMPACTS OF 1980
EXPLORATION EXPENDITURES IN CANADA

	Saskatchewan	Yukon & NWT	Other Provinces	Canada
<u>INCOME IMPACT</u> (\$1980 x 10 ⁶)				
Direct:	53.3	22.1	21.0	96.4
Indirect:	18.3	5.3	58.7	82.3
Total Income:	71.6	27.4	79.7	178.7
Multiplier:	1.3	1.2	3.8	1.9
<u>EMPLOYMENT IMPACT</u>				
Direct:	1766	602	658	3026
Indirect:	680	283	2265	3228
Total Employment:	2446	885	2923	6254
Multiplier:	1.4	1.5	4.4	2.1

4.3.2 New Mine and Mill Development

An increase in uranium production from 7000 tonnes in 1980 to 11,100-17,300 tonnes by the year 2000 will require from 4,100-10,300 tonnes of incremental mine and mill capacity. Based on the forecast mix of operations (open pit versus underground) it is estimated this will entail capital expenditures of some \$625 million to \$1.7 billion for Canada as a whole in terms of constant 1980 dollars (\$230 to \$510 million in Saskatchewan, \$330 to \$1130 million in Ontario, and \$60 to \$95 million elsewhere in the country). The impacts generated by these expenditures are summarized in Table 4.6. For Canada as a whole some \$145 to \$415 million of income will be generated directly; \$530 to \$1,480 million indirectly. The direct and indirect employment impacts in

Canada are 3,670-10,350 man-years and 20,105-55,885 man-years, respectively.

TABLE 4.6
NEW MINE/MILL CAPITAL EXPENDITURE IMPACTS
OVER THE 1980-2000 PERIOD

	Saskatchewan		Ontario		Canada	
	High	Low	High	Low	High	Low
Incremental Production (in 1000 tonnes)	4.61	2.13	4.81	1.40	10.33	4.14
Capital Expenditures (in millions of \$1980)	507	234	1130	329	1732	625
Income Impacts:						
- Direct	112	51	283	82	414	145
- Indirect	166	77	744	216	1480	527
- Total (in millions of \$1980)	278	128	1027	298	1894	672
Employment Impacts:						
- Direct	2766	1278	7071	2058	10351	3672
- Indirect	5532	2556	28991	8438	55883	20105
- Total (in man-years)	8298	3834	36062	10496	66234	23777

4.3.3 Mine Operations Impacts

The annual operating impacts of total forecast uranium production are summarized in Table 4.7 for the years 1990 and 2000.

The increase in production from 7,000 tonnes in 1980 to between 9,950-11,300 tonnes by 1990 will cause direct uranium industry income (value-added) to increase from \$630 million to \$0.9-\$1.0 billion. Indirect income generated by the industry will increase from \$160 to \$200-\$230 million for Canada as a whole. Direct employment will increase from about 5,800 jobs in 1980 to 6,100-6,900 jobs by 1990.

Indirect employment will increase from about 5,400 to 6,900-7,300.

By the year 2000 the direct and indirect income will have increased to \$1.0-\$1.6 billion and \$240-\$370 million, respectively. Direct and indirect employment will have increased to 7,500-11,700 and 3,400-13,000, respectively.

Although not shown in Table 4.7, total direct federal and provincial government revenues are estimated at \$450-\$700 million by the year 2000. About 60 percent of these revenues would accrue to provincial governments as royalties. Corporate gross earnings are estimated at \$340-\$530 million by the year 2000.⁴

The effect of a 'low' price assumption for the forecast period would be twofold:

- Absolute dollar impacts would be scaled down by the assumed percentage decline in market price. For example, assuming no corresponding increase in shipment volume and no change in cost structure, a 30 percent decline in market price (from \$100/kj or \$45/lb. to \$70/kj or about \$32/lb.) would reduce maximum potential direct and indirect income in the year 2000 from about \$1.6 billion to about \$1.1 billion.
- The relative importance of provincial royalties versus other revenue and cost categories would decline.

4.4 Comparison with Other Industries

The uranium industry has significant impacts on the Canadian economy. Directly, mine operations generate very high levels of income which accrue to government, industry and labour. Indirectly, mine operations do not generate a large amount of income and employment (because of the small proportion of material, service and labour costs out of total revenues) but mine development does exhibit high indirect or multiplier effects.

To place the economic impacts of the uranium industry in some perspective, they are compared on an absolute and per-dollar-of-revenue basis with those of other extractive and energy industries. Comparisons are based on data from a number of different studies⁵ which vary in

terms of sourcing and methodology. Also, information on particular industries may be incomplete. However, results of these studies are still considered indicative of more important differences in economic impacts.

Comparisons between the uranium and other industries are made in terms of direct (on a per-dollar and absolute basis) and indirect (i.e., income and employment multiplier) impacts. Information on forward and sideways linkages is too limited to make inter-industry comparisons.

4.4.1 Comparison of Direct and Indirect Impacts

(a) Operations

Tables 4.8, 4.9 and 4.10 summarize the direct and indirect operating impacts in absolute terms and per-million dollars of annual output for uranium, coal and other mining, and the 'extractive' phases of the oil and gas industry. The indicators selected for comparisons of direct impacts were: value of production, exports, royalties/taxes, employment, and value added. Comparison of indirect impacts are made on the basis of multipliers for each of the above industries.

The most recent common year available for comparison of direct impacts in absolute terms was 1977. Comparisons of direct impacts on a per-dollar-of-revenue basis and multipliers are made with the most recent data available which varies from industry to industry.

TABLE 4.4

COMPARISON OF DIRECT OPERATING IMPACTS OF SELECTED
EXTRACTIVE AND ENERGY INDUSTRIES
(\$1977 million unless otherwise specified)

	Ship- ments	Exports	Royalties/ Taxes	Number Employed	Value ^a Added
Uranium	349.2	305.0	143.9 ^b	3,110 ^b	310.8 ^b
Coal	699.5	596.4	69.0	9,781	508.7
Other Mining					
- Iron	1,383.6	1,114.9	51.6	15,550	824.4
- Copper/ Nickel	1,221.3	848.1	n.a.	18,113	660.5
Gas & Oil Wells	12,751.4	6,883.0	2,674.3	24,554	12,402.7

^aIncludes production factor incomes such as wages and profits as well as royalties.

^bEstimated on basis of cost breakdowns in Chapter 4.

SOURCES: Statistics Canada 11-003E, 61-207, 61-208, 1-210, 26-213, 26-206, 26-210 and 26-211.

The above table shows that for all indicators chosen, except for taxes and royalties, the uranium industry is smaller on an absolute basis than other important extractive and energy industries in Canada. Of course, for producing provinces, uranium would be much more important in the absolute sense.

On a per-dollar-value-of-shipments basis, as shown in Table 4.9, uranium ranks much higher than other types of mining, as does oil and gas, with respect to value added and, particularly, royalties and taxes. This reflects the significant rents accruing to the uranium resource, especially the rich deposits in Saskatchewan. Operating employment per dollar of shipments for uranium is lower compared to other types of metal mining, similar to that for coal, and very much higher relative to oil and gas wells for which extraction methods are very capital intensive in nature. It should

be noted that, because of the very high value and energy content per tonne of uranium, comparisons of direct impacts with other industries on a physical or energy unit basis would result in an even higher ranking for uranium.

TABLE 4.9

COMPARISON OF DIRECT OPERATING IMPACTS OF SELECTED
EXTRACTIVE AND ENERGY INDUSTRIES PER UNIT OF OUTPUT
(\$ million per \$ million of annual shipments
unless otherwise specified)

	Number Employed	Value Added	Royalties/ Taxes
Uranium (1980)	8.9	.89	.46
Coal (1973)	9.3	.75	.11
Other Mining (1978)	18.7	.67	.015
- Iron (1977)	11.2	.60	.037
- Copper/Nickel (1977)	14.8	.54	2.4.
Gas & Oil Wells (1977)	1.9	.97	.30

SOURCES: See Table 4.8.

Table 4.10 compares the indirect, or multiplier, effects of uranium mining operations with other extractive and energy industries. It shows that uranium mining has lower employment and income multipliers than other types of mining but approximately equal to oil and gas wells. Probably the most important reason for this result is that operator margin and government revenue as a proportion of operating expenditures for both uranium and oil and gas are relatively high.

This 'surplus' is not recycled in the economy to the same degree or in the same manner as direct worker incomes or expenditures on goods and services. For example, operator returns may be retained for future capital expenditures or, in the case of foreign owners, repatriated outside the

country. Government revenues may also be set aside for future use, as in the case of the provincial heritage funds.

Because of the practical and theoretical difficulties of determining the timing and proportion of surplus respending, Statistics Canada's input-output models, from which the multipliers in Table 4.9 are derived, do not take into account the economic impacts resulting from the respending of operators' netbacks and tax revenues. Thus, the use of such a model will generate higher multipliers for industries in which labour and materials comprise a larger proportion of expenditures.

TABLE 4.10
COMPARISON OF INDIRECT OPERATING IMPACTS OF SELECTED
EXTRACTIVE AND ENERGY INDUSTRIES

	Employment Multiplier	Income Multiplier
Uranium	2.0-2.6	1.1-1.3
Coal	3.3-3.4	1.6-1.9
Other Mining	2.8	1.45-1.52
- Iron	n.a.	n.a.
- Copper	n.a.	n.a.
Other Energy		
- Gas & Oil	2.2	1.25

SOURCES: Socio-Economic Impacts of the Western Canadian Coal Industry, op. cit., and Economic Impacts and Linkages of the Canadian Mining Industry, op. cit.

(b) Construction

Comparable data concerning the direct and indirect impacts of construction were readily available only for coal. Table 4.11 shows that uranium has lower capital costs per

dollar of output but higher employment and income multipliers than coal.

TABLE 4.11

COMPARISON OF THE DIRECT AND INDIRECT CONSTRUCTION
IMPACTS: COAL VERSUS URANIUM^a
(\$ million per \$ million of annual shipments
unless otherwise specified)

	Total Capital Costs	Labour/ Capital Cost	Employment Multiplier	Income Multiplier
Uranium	1.10-2.35	.22-.25	6.2-6.9	4.4-5.0
Coal	1.99-4.32	.30-.33	4.6-4.9	2.4-2.5

^aRange of estimates for open pit and underground mining methods.

SOURCE: Socio-Economic Impacts of the Western Canadian Coal Industry, op. cit.

Lower capital costs are again reflective of the high-value nature of the uranium resource. Higher multipliers for uranium reflect the more capital intensive nature (i.e., the lower labour/capital cost ratio) of uranium development. This means that the denominator in the multipliers (i.e., direct employment and labour income) will be relatively smaller for uranium versus coal and the multiplier therefore larger. It also reflects the fact that the import content of coal mine capital expenditures is larger than for uranium, largely because of the use of costly draglines in open pit thermal coal mines which are not manufactured in Canada. For example, estimated import content of open pit thermal coal capital cost is approximately 53 percent as compared to estimated import content for uranium open pit of about 32 percent.⁶ As with the operations phase, the income multipliers of mining construction are smaller than the employment multipliers because of lower average wages for indirect jobs.

Footnotes

¹See eg., Economic Impacts and Linkages of the Canadian Mining Industry, P. E. Nickel et al, Queen's University, 1978.

²See eg. The Elements of Input-Output Analysis, W. H. Miernyk, Random House, 1965.

³Defined as labour income, government royalties and other operating surplus.

⁴These estimates are for Saskatchewan and Ontario only.

⁵Socio-Economic Impacts of the Western Canadian Coal Industry, Marvin Shaffer & Associates, for the Canada West Foundation, March 1980, and Gap Analysis of the Western Canada Labour Market, DREE, February 1980, and Economic Impacts and Linkages of the Canadian Mining Industry, P. E. Nickel et al, Queen's University, 1978.

⁶See, Western Electric Power Grid Benefit Study: Socio-Economic Impact Analysis, Marvin Shaffer & Associates, October 1980, and Economic Impact of Key Lake Uranium Project on Saskatchewan, op. cit., for the above import content estimates.

Chapter 5

ENVIRONMENTAL IMPACTS OF URANIUM MINING

5.1 Introduction

Estimates of the capital and annual costs of environmental and safety regulations borne by the uranium mining industry in Canada were made in Chapter 2. These costs amounted to about 6.8 percent of 1980 uranium shipments, while the value of total capital investments comprised about 21.5 percent of estimated annual sales. These are costs which have been internalized by the industry and are, therefore, included in the total unit costs estimated in Chapter 3.

This chapter attempts to summarize those environmental and safety impacts of uranium mining which are borne by the public and workers in the industry, and to which dollar values cannot be readily attached. Possible mitigation measures and the adequacy of the current regulatory framework are also briefly discussed.

External social costs associated with uranium mining or any industry are extremely difficult to estimate in dollar terms. Risk analyses attempt to systematically identify and quantify the environmental, health and safety risks of different forms of mining and energy production so that they can be assessed on a comparable basis. A brief summary of some recent comparative risk analyses is presented at the end of this chapter.

The most important way in which the environmental impacts of uranium mining differ from most other types of mining is that it involves radiological hazards in the short and long-term,¹ including:

- risks to public health and safety due to ground surface water contamination and airborne emission
- occupational health and safety hazards due to radiological exposure at the workplace

This discussion of environmental impacts is general in nature and it should be kept in mind that each mine has its own unique set of circumstances which affect the economic and environmental impacts. It should be noted, as well, that more stringent regulatory standards and improved operator practices have reduced the environmental and health impacts of Canadian uranium mining relative to historical experience.

5.2 Exploration

Environmental impacts of uranium exploration can occur in the following stages:

- road building
- stripping, trenching and test pitting
- drilling
- adits and shafts
- sample and core storage

There is little information available on the hazards of uranium exploration. The Bates Inquiry concluded that physical hazards (i.e., accidents) were far more important than radiological hazards and that the latter were significant only in the advanced stages of exploration which approached mining on a small scale. Therefore, it was recommended that exploration in B.C. be allowed to proceed with strict adherence to existing and recommended safety measures. It also recommended that the driving of adits and shafts, which are required to determine the nature and extent of the ore body, be treated as tantamount to underground mining. Stringent safety measures and monitoring to prevent contamination of underground water supplies were also proposed.

5.3 Mining and Milling

5.3.1 Radiological Hazards

(a) Occupational Hazards

These result primarily from long-term exposure, externally and through inhalation, to radionuclides. For example, evidence presented before the Ontario Royal Commission of Inquiry into Uranium Mining,² the Cluff Lake Board

of Inquiry in Saskatchewan³ and the incompleted B.C. Royal Commission of Inquiry into Uranium Mining⁴ generally suggested higher than normal incidence of cancers among uranium workers. This was indicated, in particular, as a danger among underground miners and for miners who also smoke. The conclusiveness of the evidence varied and came from a period when health and safety standards were not as stringent or as rigorously enforced as at present.

(b) Environmental and Public Hazards

The public can be exposed to radiological hazards of uranium mining and milling in a number of ways:

- Lowering of water tables in underground or open pit mines (by means of ringwells or sumps to facilitate extraction) can result in exposure of radioactive elements to the environment.
- Leaching of radium-226 and other radionuclides by flowing sump water or rainwater on exposed ore surfaces may later be distributed into the biosphere.
- Radon gas emissions may come from open pits or underground venting.
- Dust may be created by ore transport and the mining operations generally, particularly in open pit operations.
- Radon emissions and dissolved toxins from mine and mill waste can enter the biosphere and subsequently enter food chains.

Generally, hazards to public health and safety are higher the nearer one lives to a uranium mine or mill site. Workers at a mine/mill site who reside nearby face greater risk than other residents of the same town or mine/mill workers who live farther from the work site.

Normal background radiation levels result in an expected mortality rate of about 400 deaths per million of population. The U.S. Nuclear Regulatory Commission (NRC), in a draft impact statement on uranium milling,⁵ concluded that on the basis of past practices, the odds of premature death due to lung cancer of residents living within 2 kilometres of a uranium mill for 20 years were 40 percent

greater than this. This view probably overstates the impact of new or upgraded mills due to more stringent standards. The NRC further concluded that this risk would be doubled for residents living near a site where milling and mining are carried on together. Risks to individuals living beyond 2 kilometres from the mine were estimated to be a small fraction of those living nearby.

The Cluff Lake Board of Inquiry concluded that public hazards of uranium mining and milling in the short-term would be negligible beyond a distance of 1 or 2 kilometres. Radon emissions were considered to be undistinguishable from background levels at this distance and gamma ray intensities negligible at even shorter distances. The Inquiry was of the opinion that adherence to dust and water control standards would ensure no public hazards from these sources.

The long-term hazards associated with mine waste and tailings piles were also considered to be negligible by the Cluff Lake Inquiry at distances beyond 2 kilometres if adequate measures were taken to prevent excessive leaching or wind erosion of the piles. For example, the Inquiry cited evidence which indicated that increases in lung cancer incidence in persons living 2.2 kilometres from uncovered tailings piles would amount to only 1 percent above the normal level. (Such an increase would not be considered to be statistically significant.)

The Environmental Assessment Board of Newfoundland recently conducted hearings on the Kitts-Michelin uranium mine in Labrador proposed by Brinex Newfoundland Exploration Ltd.⁶ It recommended the project be denied a development licence until such time as it could ensure the safe and permanent disposal of waste materials.

5.3.2 Non-Radiological Hazards

(a) Occupational Hazards

Non-radiological hazards include a relatively high accident rate common to other types of mining and particularly to underground mines. Underground mines at Elliot Lake, Ontario also have a very high silica content in mine dust which has represented a serious health hazard to workers in the form of silicosis. However, with improved ventilation,

improvements have been made in the level of silica in the working areas.

(b) Environmental and Public Hazards

Generally these impacts are similar in nature to those of other forms of mining and include:

- resource devaluation or loss altogether of alternative land uses in the area of the mine, mill and waste storage sites; also as a result of ancillary developments such as transportation and power corridors and townsite developments
- up-take of non-radiological contaminants into the atmosphere and leaching or runoff into water systems, primarily of chemical compounds used in milling and heavy metals or sulphides contained in the ore
- up-take of dust into the atmosphere from exposed ore bodies and mining operations, ore transport and milling

5.4 Mitigation of Impacts

The impact of uranium mining on public and worker health and safety and the environment generally is a function of mitigation measures and their costs. Examples of such measures, many of which have already been adopted, are:

- Use of tailings ponds for the treatment of mine water to allow for settling of wastes (precipitation can be aided by flocculants and filtration) can prevent contamination of nearby water sources.
- Line the bottom of tailings ponds with an impermeable layer such as clay or concrete in order to prevent seepage. As part of a long-term surveillance program, drill monitoring wells so that groundwater may be recycled to the pond if contaminated. It has been estimated that covering the pile with about 6 metres of earth and revegetating the area at the end of the mine operation would reduce radon emissions by about 90 percent and prevent wind erosion.⁷ Contouring the surface of the pile covering and appropriate ditching can lessen rain and runoff erosion.

- Place exceptionally high grade waste tailings in concrete vaults and the cover such vaults with asphalt.
- Measures to improve worker health and safety include the following: ventilation; shielding of individuals and machinery; procedures and equipment for dealing with unusual or emergency situations during operations, such as equipment failure; the use of filters on equipment and in breathing apparatus which remove virtually all radon daughters; equipping of rock drills and other machinery with dust collectors or electrostatic precipitators; good mining practices such as annual rotation of workers, dust suppression, and regular monitoring of individuals; machinery and work areas with dosimeters; and worker education programs.

Generally speaking, the level of risk to uranium mine/mill workers and public health and safety factors both tend to improve with increased public and private mitigation efforts. In the view of both the Cluff Lake and Bates Inquiries, standard-setting should result in risk levels "as low as reasonably achievable, social and economic factors being taken into account" (this is known as the ALARA principle). This is not a clear-cut criterion. It is difficult to quantify the cost-risk trade-off because the effects of radiological hazards are not precisely known, particularly over the long-term, and because human morbidity cannot be acceptably expressed in economic terms. Essentially, standard setting becomes a political process in the sense that it must involve a resolution of input from the public, industry, labour unions and, finally, the appropriate regulatory authorities.

5.5 Risk Analysis

Efforts to systematically identify and quantify the health and safety risks of different activities so that they can be assessed on a comparable basis involve risk analysis. While such analyses, particularly those embracing the nuclear fuel cycle, have been criticized on methodological grounds, the concept of expressing social costs on a common basis is generally supported.⁸

The Cluff Lake Inquiry concluded that the estimated fatality rate for that particular open pit operation, approximately 500 per year per million workers,⁹ would be comparable to that estimated by the Saskatchewan Department of Labour and the Ontario Man Commission for other Saskatchewan mines and steel workers, and considerably lower than for underground miners, loggers, railroad workers and fire fighters.¹⁰ Historical data for underground uranium mining in Ontario would show a higher risk rating because of its higher accident rate and the silicosis problem there.¹¹

Ripley et al, in a study for the Centre for Resource Studies at Queen's University,¹² formulated an environmental impact matrix for the Canadian mining industry which included a number of metallic and non-metallic minerals such as iron, coal, uranium and potash. On the basis of information compiled by the authors, largely from previously published material, the magnitude of impacts of different types of mining upon a number of resource and environmental categories were estimated on a scale of 1 to 10. The authors acknowledged that the assignment of such scales involves subjective, generalized judgments and stressed that this technique can only serve to give an overall impression of the relative environmental impacts of various forms of mining. There are two rankings for each type of mining: maximum potential impacts and actual impacts in light of such factors as pollution controls and regulatory standards and location.¹³

Generally, uranium mining ranked the highest with respect to potential impacts on water-related resources and human health. It also ranked relatively high in terms of potential impacts on natural wilderness areas, forestry, wildlife trapping and hunting and agriculture. However, when actual regulatory and locational factors were taken into account, the overall impact of uranium relative to other forms of mining dropped significantly. With respect to impacts on human health, uranium mining remained the highest ranked, along with mining and milling of sulphide ores and mining of structural materials.

Estimates of the relative occupational and public risk of uranium mining versus coal mining have been made by Inhaber of the AECB.¹⁴ On a per-megawatt-year net energy

output basis, uranium mining had a much higher degree of risk than coal mining in terms of man-days lost to accidents and disease. On the other hand, the overall risk of nuclear power was considered much lower than the corresponding factor for coal-generated power.¹⁵ The explanation for this is that uranium mining accounts for about 75 percent of the overall risk of the nuclear fuel cycle, whereas the corresponding proportion for coal was only about 10 percent. This study also estimated that 85 percent of the risk of the entire nuclear fuel cycle is associated with occupational accidents and disease.

Other analysts have argued that the public and occupational risks of the nuclear industry, when examined over the entire fuel cycle, are low relative to other energy sources. For example, P. G. Hill, in a study for the Ontario Royal Commission on Electric Power Planning,¹⁶ concluded that the public and occupational risk may be an order of magnitude less for nuclear than for coal-fired power generation. The broader environmental effects of thermal power generation, primarily due to air pollution and acid rain, were also determined to be much greater in magnitude than for nuclear.

As suggested in the introduction to this study, the risks of uranium mining and the nuclear industry are generally perceived to be higher than for other energy sources by the public because of their radiological and long-term nature.¹⁷ Hoheneser et al recognize the causes for this perception but conclude that the quantified risks, based on available information, are much larger for coal and hydro than for nuclear power taken over the entire fuel cycle.¹⁸

5.6 Summary of Environmental Impacts

In summary, it should be stressed again that the nature and importance of environmental impacts will vary from mine to mine and that some of the evidence upon which the above discussion is based was derived from a period when health and safety standards were not as stringent as at present.

Uranium mining appears to account for most of the environmental and health risks of the nuclear fuel cycle. Direct public risks attributable to uranium mining and

milling are generally considered minimal beyond the immediate vicinity of mining and milling operations.

The studies reviewed indicated that occupational hazards comprised the most important part of the health risks associated with uranium mining. The incidence of radiologically-induced lung cancers in uranium mining has been higher than for the population at large. The radiological health hazard is even greater for those workers living near the mine and who also smoke. A significant proportion of occupational risks are attributable to non-radiologically-induced diseases (i.e., silicosis in underground uranium mines at Elliot Lake) and accidents. Occupational risks in Ontario uranium mines were found to be significantly higher than in open pit mines in Saskatchewan due to their much higher accident rate and the problem of silicosis.

Stringent regulatory controls, particularly with respect to worker health and safety and long-term waste disposal, can reduce hazards greatly. However, it is almost impossible to subject such controls to cost-benefit calculations (i.e., to impose standards to the point where the costs just equal benefits) because of the difficulties involved in identifying, measuring and placing a value upon the benefit of improved standards. While concerns have been expressed in public inquiries regarding the standard-setting process, it nevertheless is true that the uranium industry is one of the most stringently regulated in Canada.

In comparing uranium mining with other extractive industries it appears that on the basis of recent historical data the latter would involve greater environmental impacts because of much greater volume of throughput and associated land use and transportation requirements.

Evidence with respect to the comparative occupational and public health risks of uranium mining is varied. It suggests that, while not unique in this respect, uranium mining may pose greater public and worker health risks on a per-unit output basis than many other industries. This is particularly true of underground mining in the Elliot Lake region, which involves not only a high accident rate common to other types of underground mining but, in addition, the hazards of silicosis and radiologically-induced cancers.

Footnotes

¹Uranium mining is not entirely unique in this respect. Other types of mining may also involve hazards due to their content of toxic, even radioactive, elements. For example, uranium does occur naturally with coal, copper and phosphate rock and, in some cases, with molybdenum and gold.

²Report of the Royal Commission on the Health and Safety of Workers in Mines, Dr. J. H. Ham (Chairman), 1976, Government of Ontario.

³The Cluff Lake Board of Inquiry: Final Report, Hon. Mr. Justice E. G. Bayda (Chairman), 1978, Government of Saskatchewan.

⁴Royal Commission of Inquiry into Uranium Mining, D. W. Bates, M.D. (Chairman), 1980, Government of British Columbia.

⁵Draft Generic Environmental Impact Statement on Uranium Milling, Summary and Text, U.S. Nuclear Regulatory Commission, 1979.

⁶Brinex Kitts-Michelin Uranium Project, Report of the Environmental Assessment Board, April 1980.

⁷The Cluff Lake Board of Inquiry: Final Report, op. cit., p. 109.

⁸For example, see Cost-Risk-Benefit Assessments in Energy Policy, A. Lovins, George Washington Law Review, Vol. 45, No. 5, August 1977.

⁹About two-thirds of the fatalities would be delayed cancer deaths and the balance due to industrial accidents. In terms of man-years of life lost, industrial accidents would account for more than one-third of the total.

¹⁰Fatality rates for these industries were related to accidents and did not include possible delayed deaths due to exposures to other hazards. Therefore in most cases these comparisons overstate the relative hazard of uranium mining.

¹¹See The Report of the Royal Commission on the Health & Safety of Workers in Mines, J. H. Ham Commission, June 1976.

¹²Environmental Impact of Mining in Canada, E. A. Ripley et al, for Centre for Resource Studies, Queen's University, 1978.

¹³Locational factors would include the presence or absence of particular ecosystems, the size and distribution of operations and the effectiveness of dispersion processes.

¹⁴Risk of Energy Production, H. Innhaber, Atomic Energy Control Board, November 1978.

¹⁵As well as for all other energy sources, conventional and non-conventional, except for natural gas.

¹⁶The Social Costs of Electric Power Generation, P. G. Hill, for Royal Commission on Electric Power Planning, 1977.

¹⁷For example, see The Process of Risk Assessment in Nation 1, Provincial and Local Policy Decisions on Nuclear Power, I. Burton, A. Whyte, University of Toronto, November 1977.

¹⁸The Distrust of Nuclear Power, C. Hohenemser et al, in Science, Vol. 196.

Chapter 6

OVERALL ASSESSMENT OF URANIUM MINING

6.1 Introduction

The purpose of this chapter is to compare the overall economic and environmental impacts of uranium mining with other energy and extractive industries in Canada.

A discussion of the distribution of costs and benefits of uranium mining, including local multiplier and social impacts, is also included. Finally, possible measures which might be implemented to maximize the net benefits of uranium mining are outlined.

6.2 Economic Impacts of Uranium Mining¹

6.2.1 The Magnitude of Economic Impacts

The potential economic impact of uranium mine development and operations is substantial in absolute, and particularly, in per-unit output terms. Depending on market factors and supply constraints, uranium mine development in Canada could generate, directly and indirectly, up to \$1.9 billion in income and 66,000 man-years of employment over the 1980-2000 period. Mine operations, directly and indirectly, could generate up to \$1.9 billion in income and 25,000 jobs per year by the year 2000. Export earnings generated by uranium mining in Canada could reach \$1.5 billion in 1980 by the year 2000. Government income tax and royalties could amount to \$700 million annually by the year 2000. These estimates do not include the impacts of uranium exploration or townsite and other infrastructure development.

6.2.2 The Distribution of Economic Impacts

(a) Inter- and Intra-Provincial Distribution

The bulk of direct and indirect employment and income impacts of uranium mining development and operations

are centred in Ontario. This obviously is related to the production volume forecasts by province but is also related to the following:

- The higher cost nature of underground, lower grade mines in Ontario, result in higher direct impacts per kilogram of output.
- Multiplier effects are also higher in Ontario because of the greater maturity of the economy, (see Tables 4.2-4.5) particularly with respect to the manufacture of machinery and equipment.²

The Saskatchewan government, however, receives a greater share of projected tax and royalty revenues because of the very high rents associated with its high grade uranium resources and a progressively structured system designed to capture these rents.³

Within uranium-producing provinces, the direct operational employment and wage impacts are by far the most important felt at or near the mine site. Other income or value-added components of the operations phase such as corporate profits and debt repayment will accrue primarily to non-local residents. Inter-industry impacts will be minimal due to the inability of the local economy, often in remote locations, to produce the goods and services required for project operations.⁴ Other local economic impacts could include the upgrading of road and/or air transportation, labour force training, improved health services and reduction in government subsidies.

Leakages from the regional economy are usually even more pronounced during mine construction. The size and skill range of the local labour pool is generally inadequate, particularly given the short time scale of such projects. Also the local economy is generally not capable of producing the machinery and equipment required for construction.

Because of the high leakage factors discussed above, local multipliers for the uranium industry will be quite small. In light of the provincial multipliers estimated in this study⁵ local income and employment multipliers for Ontario mines might be in the order of 1.4 and 1.1, respectively, while those for Saskatchewan mines would be roughly 1.2 and only very slightly above 1.0. That is, the leakages

from a typical mining operation in Saskatchewan are so great that almost no indirect employment is created locally.

(b) International Distribution

Most of the direct and indirect impacts of uranium mining, such as taxes, royalties, and expenditures on supplies and equipment, accrue to the Canadian rather than foreign economies. For example, Statistics Canada's input-output model shows that foreign sourcing of direct purchases accounted for only about 1 percent of operating materials and supplies and about 15 percent of total construction costs.⁶

However, because of the fairly high degree of foreign ownership, there is a more significant leakage from the Canadian economy with respect to corporate earnings (retained or distributed as dividends) and debt payments. If such leakages were directly proportional to the volume of uranium production controlled by foreign interests, they could total up to about \$384 million annually by the year 2000. It is likely actual leakages of gross operator margin would be less than this, since a proportion would be used to finance exploration and development of uranium or other resources in Canada.

6.2.3 Comparison with Other Industries

(a) Magnitudes of Impacts

On a per-dollar or a per-kilogram output basis, uranium ranks much higher than other types of mining with respect to total value added⁷ and royalties and taxes directly generated in the operations phase. This reflects the significant rents accruing to the uranium resource, especially the rich deposits in Saskatchewan, and in this respect it is similar to the oil and gas industry. Operating employment and export earnings per kilogram of output are also much higher than for the other energy and extractive industries selected for comparison.

Employment and income multipliers in the operation phase for uranium are lower than for other types of mining (at the local, provincial and national levels) and comparable with oil and gas. This is primarily because operator margin and government revenue as a proportion of total expenditures

are relatively high in the uranium industry. The timing and proportion of surplus responding is uncertain from a practical and theoretical viewpoint and therefore input-output models generally do not incorporate them in their multipliers. If the responding of these value-added items was taken into account, provincial and national multipliers for uranium would be increased but the local multiplier for uranium would be unaffected. It would still be smaller than for most other extractive industries.

Total capital and employment costs associated with uranium mining development are lower on a per-dollar-of-output but higher on a per-kilogram basis than for coal, the only industry for which such data was readily available. However, similar results would also be likely for other types of mining, given uranium's very high value per kilogram. Uranium has higher employment and income multipliers than coal in the construction phase, probably as a result of its more capital-intensive nature and the lower import content of such expenditures. Comparisons with other industries are not possible at this time since construction multipliers for them are not available.

(b) Distribution of Impacts

Readily available data on the distribution of economic impacts for various extractive and energy industries are limited but some tentative remarks can be made here. With regard to the provincial distribution of direct impacts, coal, oil and gas industries during operation and construction phases have a proportionately greater impact on the western provinces, whereas uranium and other metal mining are oriented more to Ontario. The multiplier effects for all of these industries impact the Ontario economy disproportionately to the incidence of direct impacts.

All extractive and energy industries, including uranium, can have substantial direct employment and wage impacts on local economies during construction and operation but such impacts are usually relatively small in relation to the overall size of the project due to leakages. Direct and indirect expenditures and income will accrue primarily to non-local residents. The share of total employment and income impacts accruing to local residents will be somewhat

lower for uranium than most other extractive industries because of its high tax and profit content and lower local multiplier effects.

Little can be said concerning the international distribution of operating and capital expenditures of uranium mining versus other industries, except that, with respect to materials and supplies, uranium is unlikely to rank significantly lower in terms of domestic content. We do know that the import content of open pit thermal coal construction is significantly higher than for an open pit uranium mine. With respect to components of operator margin such as corporate profits, the degree of foreign ownership in the uranium industry versus other energy and extractive industries suggests that foreign remittances of such payments may be higher in uranium on a per-unit basis than in other types of metal mining but comparable to, or less than, coal, oil or gas.⁸

6.3 Environmental Impacts of Uranium Mining

6.3.1 The Magnitude of Environmental Impacts

The uranium industry internalizes substantial environmental and safety costs. A current estimate by Secor, Inc. places these annual costs at about 6.8 percent of operating revenues or about \$6.80/kg of uranium shipped. Moreover, capital costs are also incurred. These costs will likely continue to rise, perhaps even at a faster rate than other expenditures if regulatory standards are raised or enforced more stringently in the future.

With respect to unmitigated environmental impacts,⁹ a number of studies and public inquiries reviewed for this assessment showed considerable variation in evidence and opinion, particularly concerning the long-term radiological hazards to workers and the public of uranium mining. Evidence suggests that direct public risks are considered minimal beyond the immediate vicinity of a mine and mill. Occupational hazards, which probably constitute the greatest proportion of total risk in uranium mining, include greater than average lung cancer rates, a high accident rate and, at Elliot Lake, the additional problem of silicosis. Occupa-

tional risks in Ontario underground mines are generally found to be higher than for Saskatchewan open pit mines. The magnitude of such impacts has probably been reduced considerably in recent years due to more stringent regulatory standards.

6.3.2 Distribution of Environmental Impacts

Unlike economic impacts, which involve significant leakages beyond the regional economy, the environmental, health, safety and social impacts of uranium mining are generally very localized in nature. Thus, local and regional residents bear a disproportionate share of social costs in comparison with their share of economic benefits. Conversely, non-local governments and residents receive a disproportionate share of tax and income benefits in comparison with their share of external costs.

6.3.3 Comparison with Other Industries

(a) Magnitude of Impacts

A review of a number of recent comparative risk studies has shown varied results. On the basis of this review it appears that uranium mining may involve greater public and worker health risks (particularly on a per-unit output or energy basis) but lower non-health environmental costs than many other forms of mineral extraction. A number of sources have indicated that the entire nuclear fuel cycle has lower environmental and health costs associated with it than most other forms of energy production.

(b) Distribution of Impacts

With respect to the distribution of environmental and social costs, other extractive and energy industries are similar to uranium mining in that local residents bear a disproportionate share of the external costs while non-local residents receive a disproportionate share of the benefits. On the basis of evidence surveyed for this study, it appears that the disproportionate distribution of social costs and economic benefits is more marked with respect to uranium because of its significant health and environmental impacts and very high economic leakages.

6.4 Overall Assessment

As stated above, the approach taken in this study has been to compare the overall economic, environmental and social impacts with those of other extractive and energy industries.

In general terms, the uranium industry in Canada generates substantial economic benefits in terms of taxes and royalties, income, employment, foreign exchange earnings, security of energy supply and technological spinoffs. On a per-unit output basis, only the oil and gas industry generates comparable direct economic benefits. The indirect impacts of the uranium industry at the subprovincial, provincial and national levels, as measured by employment and income multipliers, are lower than those for other types of mining and comparable for oil and gas primarily because of the high proportion of costs 'withdrawn' from the economy in the form of taxes and operator margin.

Associated with these economic benefits are significant social costs--particularly occupational hazards associated with underground mining. But uranium mining probably has a lower non-health environmental impact than other mining industries due to much smaller throughputs and transportation requirements. The distribution of costs and benefits is such that residents of the area surrounding a uranium mine bear a disproportionate share of the social costs while non-residents receive a disproportionate share of the benefits. Other resource industries also have this characteristic but it appears to be more pronounced in the case of uranium mining because of its significant health and environmental impacts and its very high economic leakages.

A detailed assessment of the entire nuclear fuel cycle in comparison with other energy sources was beyond the terms of reference of this study. Nevertheless, based on the review of a number of studies, it appears that cost-benefit comparisons on a fuel cycle basis are definitely more favourable to the uranium industry than comparisons made on the basis of the mining/milling stage only.

There are several areas in which efforts to maximize the net benefits of the uranium industry in Canada might be desirable: mitigation of health and environmental impacts;

redistribution of economic benefits; and efforts to expand and stabilize the domestic and export markets for Canada's uranium. These suggestions are based on our review of specific recommendations contained in a number of studies and public inquiries into the uranium industry.

Some of the measures cited are now being implemented or actively considered, particularly by provincial governments, in response to recommendations of various public inquiries. Also, the measures outlined below are very general in nature. It is beyond the scope of this study to describe specific mechanisms for their implementation, since they will vary by jurisdiction and type of operation.

6.4.1 Mitigation of Health and Environmental Impacts

A number of mitigation measures were outlined in Chapter 5 including the design of tailings ponds and the adoption of mining practices such as machinery shielding and worker rotation and monitoring. These measures are only a representative sample of specific recommendations made by various public inquiries into uranium mining or the uranium fuel cycle. The appropriate set of measures will vary from project to project but all appear to be technically feasible, and many are now being adopted and enforced within the industry. Subject to the stringent enforcement and monitoring of standards, uranium mines can be operated within generally acceptable limits of health and environmental impacts.

However, the long-term waste disposal problem has not yet been satisfactorily resolved and research to this end is perhaps the single most important initiative remaining to reduce the social costs of uranium mining in Canada. For this reason, sufficient funds should be set aside to ensure that monitoring or mitigation costs incurred in the post-operational phases of uranium mining or downstream activities can be fully met. In the author's view, such costs should be internalized. Thus, the industry should be the primary contributor to such a fund.

While concerns have been expressed in public inquiries regarding the standard-setting process, it is nevertheless true that the uranium industry is one of the most

stringently regulated in Canada. The key to this process is to ensure that it is based upon independently derived scientific data and that it is as open to independent scrutiny as possible. This is particularly important in view of the public's perception of the uranium industry as somehow unique in terms of its environmental and health-related impacts. Finally, such standards and practices should be regularly reviewed so that new information and experience can be taken into account.

6.4.2 Redistribution of Economic Benefits

Local and regional residents could receive a greater share of economic benefits in view of the fact that they bear most of the environmental and health impacts of uranium mining.

One means by which this redistribution has been traditionally approached is by making regulatory approval of a particular project conditional upon preferential hiring and training of local residents and purchases from local businesses.¹⁰ While such policies are helpful they are not likely to result in significant and permanent redistribution of economic benefits to local residents for two reasons:

- Labour and materials costs comprise a small proportion of the total costs of uranium mine operation.
- Natural impediments to local participation, such as lack of skills and inadequate scale and diversity of manufacturing, will persist even at high levels of subsidization.

More fundamental distribution mechanisms have been proposed, such as sharing of resource royalties and conferring greater control to regions through local government or greater representation on relevant policy-making bodies. Such measures may have merit but they require careful analysis because they have implications for the allocation of other resource revenues and the structure of the political system itself.

6.4.3 Marketing

Aside from continued and expanded efforts to maintain and increase sales of Canadian uranium abroad, an important means of increasing the net benefits of our uranium industry is to participate in efforts to prevent over-supply and further price de-stabilization in world markets. This is important given that provincial uranium royalty revenues are severely affected by falling uranium prices and that the economies of local areas of the producing provinces are highly dependent on continued viability of the industry.

Footnotes

¹It should be noted that all dollar values are in constant \$1980, that development impacts refer to new investments in uranium mining over the 1980-2000 period and that operational impacts represent annual levels of activity of existing and new mines.

²In fact, there are significant leakages from Saskatchewan and other uranium-producing provinces to Ontario.

³If revenues accruing to the Saskatchewan Mining Development Corporation were also considered as government revenues, their distribution would be even more skewed in favour of Saskatchewan.

⁴Estimates for the Cluff Lake Project by Inter-Group Consultants, op. cit., show that only 12 percent of total project expenditures accrue to northern Saskatchewan residents.

⁵See Tables 4.4 and 4.5.

⁶Estimated Canadian sourcing of capital and operating expenditures for the Cluff Lake open pit mine in Saskatchewan was 89 percent.

⁷Defined as the sum of labour income, gross operator margin, government royalties and corporate income taxes.

⁸Based on Statistics Canada 61-207 and 61-208.

⁹That is, impacts borne by the public as workers.

¹⁰This approach has been adopted by the Saskatchewan Government with regard to uranium development.



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- No. 1 The Availability of Capital to Fund the Development of Canadian Energy Supplies. J. R. Downs. November 1977 (Price \$3.00, 109 pages) ISBN 0-920522-00-9.
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